JOURNAL

OF THE

ROYAL GEOLOGICAL SOCIETY

OF IRELAND.

VOL. XV.—~~PART III.~~

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JOURNAL

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ROYAL GEOLOGICAL SOCIETY OF IRELAND.

I.—ANNUAL ADDRESS

BY

The Rev. MAXWELL CLOSE, M.A., President, R.G.S.I.

[Read February 18, 1878.]

As this is the first anniversary meeting of the Royal Geological Society of Ireland, which has been held in connection with the Royal Dublin Society, it behoves us, as members of the former, to begin our proceedings with a reference to the new conditions in which we find ourselves. We would heartily congratulate ourselves on the alliance which has been effected between the two Societies; it is calculated to be beneficial to us in various ways. Our modesty prevents our congratulating the members of the Royal Dublin Society, in their presence, on the alliance; but we may express our desire and hope that the benefit may be mutual. We are not called upon to confess whether that hope be accompanied with expectation; but, judging from the way in which our newly found allies have favoured us with their presence and countenance, we venture to surmise that they are not altogether devoid of such expectation themselves.

The nature of the connexion between the two Societies is, as you are aware, best indicated by the word which has been chosen to describe it, viz., "Association." There is no amalgamation, incorporation, affiliation, &c.; each Society still remains quite separate and distinct. The Geological Society retains its own individuality and autonomy just as before. We hope we may be excused for pointing out on the present occasion, as a matter of business, yet with an earnest μὴ γένοιτο, that should it ever become necessary, the association of the two Societies can be dissolved as easily as it was effected.

To turn to our own special concerns—As we have just entered upon new conditions, though not upon a new stage of existence, this has been regarded as a suitable opportunity for introducing

a new feature into our operations. We have had, at various times, field excursions to places in the neighbourhood of special geological interest. It is now proposed to make this a regular annual proceeding, which we hope will lend additional attraction to our Society. We must turn again to business and point out that the annual field excursion, so pleasant, not only geologically, but otherwise, also, is to be only for our own Fellows, and that our allies of the Royal Dublin Society, in order to partake of the advantages thereof, must become naturalized as Fellows of our Society. The precise arrangements have not yet been decided upon; but when they are they will be made known.

It is the usual, but not invariable, practice to give in the Anniversary Address a *résumé* of our proceedings during the past year. I propose to omit this on the present occasion, there being precedent for so doing, and to invite the attention of the Society to a matter which is to geologists of the utmost importance, viz., *the physical argument for the restriction of geological time.* Though this is a question which lies somewhat out of the usual line of geological discussion, we cannot afford to pass it by. When cosmogonical or semi-cosmogonical arguments are brought against what seem to be in themselves unavoidable geological conclusions we are compelled to go into those arguments for ourselves. As the question we have to consider is by no means a new one, we may enter upon it at once without any further preface.

Professors Sir William Thomson and Guthrie Tait object, as physicists, to the geologists, that, for several reasons, the whole reach of geological time must be very much less than that which is generally supposed to be necessary for the explanation of various geological phenomena. We need not now go into the reasons for believing that the geological changes, operations, and evolutions, of which we see evidence, must have required an enormous space of time for their accomplishment. The argument from denudation, for instance, has been very strongly presented, quite lately, by Dr. Croll in the Quarterly Journal of Science, July, 1877. Let us, however, acknowledge that some geologists have been too free in the assumption that they had practically unlimited time at their disposal; they were looking at things too exclusively from their own point of view, and needed to have it pointed out to them that there were other *momenta* of the question which they were

altogether neglecting. Let us cheerfully acknowledge our obligations to the physicists for having impressed this upon us; restriction and limitation is often a positive, and not a mere negative boon; it is often a partial guidance towards the goal of truth. Our present object is by no means to escape from wholesome *re*striction, but only to relax the intolerable *con*striction to which the physicists, in their over-zeal for our welfare, would subject us.

Sir W. Thomson's argument was first drawn out in full in a paper communicated to the Geological Society of Glasgow, in 1868; but it had been already partly put forth in former papers, as in that on the Secular Cooling of the Earth (Trans. Roy. Soc. Edinb. 1862), and in others.

Professor Huxley replied in his Presidential Address to the Geological Society of London in 1869, but apparently without effect, for we find Professor Tait repeating the arguments, with his own modifications, in some lectures delivered in Edinburgh in 1874. These lectures were published in the early part of 1876, and in the latter part of the same year Sir William himself repeated one of them in his Address to the Mathematical and Physical Section of the British Association, at Glasgow.

We shall not now bring up any of Professor Huxley's arguments in reply excepting one.* Of course in the following observations, as far as they are correct, we shall be only reminding our opponents of matters which they know better than we do, but which they have overlooked, while fixing their attention so strongly upon their own side of the question.

Let us, then, take their three arguments as they are presented to us again by Professor Tait,† since Professor Huxley's reply. The first is drawn from the rate of the earth's secular cooling; the second from the figure of the earth considered in connection with its present rate of rotation, as retarded by the action of the tides; the third from the comparatively short time that the sun can be imagined to have kept, by its radiation, the earth's surface in a state fit for the support of animal and vegetable life.

A.—In our consideration of these arguments, it will be more suitable to invert their order, and to begin with the last mentioned, viz., that drawn from the length of time that the sun

* See his Pres. Address in Quart. Journ. Geol. Soc., Lond., vol. xxv., 1869.
† Recent Advances in Physical Science, pp. 165 *et seq.*

can be imagined to have kept the earth, by its radiation, in a fit state for the habitation of animals and vegetables. Professor Tait says that this cannot have been more than fifteen or twenty millions of years. But this question is one that cannot be settled by calculation, owing to our ignorance of some important elements of it. Granting the nebular hypothesis of the origin of the solar system, it is highly probable that the sun must have been formerly much hotter than it is at present; and if the earth (though sufficiently cool of itself) were fully exposed to the strength of his heat, no organic life, such as we know of, could have existed on the earth until after the sun had been cooling for a very long time; so that in that way a very considerable part of the sun's duration would be lost for geological time. But, as Professor Tait himself points out, "we can imagine that one effect of his heat was to throw off from his surface such enormous clouds of absorbing vapour, which cooled as they left the surface, that the effective amount of radiation reaching the earth might not have been greater than at present;" and, besides, the greater amount of vapour in the earth's atmosphere may have helped to produce this effect. It is utterly impossible to calculate what the effect of this cloud-screen may have been on the radiation of the sun; but Professor Tait states, in p. 175 of the book from which we are quoting, that if it made the sun to cool *even at a uniform rate*, it could not give us more than fifteen or twenty millions of years for the time of organic life on the earth. But he seems to have forgotten another estimate given before, in p. 154 of the same book. He says: "We find by calculations in which there is no possibility of large error that this [nebular] hypothesis is thoroughly competent to explain 100 millions of years' solar radiation *at the present rate*, perhaps more." On comparing p. 152, it will be seen that this refers to past radiation only. It does not not apply to the whole, including future radiation. If the sun should have been losing heat uniformly, and at the present rate, it would make no difference how that uniformity had been attained, whether by a cloud-screen or otherwise; the period of cooling must be the same; and yet we find two such different estimates given by the same writer as fifteen or twenty millions on one hand and a hundred millions of years on the other; the latter number being five or six times greater than the former one, and being, moreover, the one proposed with the greater appearance of confidence. Of

course the reason of this discrepancy is that the estimates were made on different data, or, to use the more correct expression, assumptions. One assumption that is always made is, that the original nebula was cold when it began to fall together, and also that it had nothing but the potential energy of gravitation with which to accomplish its evolution; of course some such assumptions must be made before any calculation can be applied. But Dr. Croll well remarks, "It is quite conceivable that the nebulous mass may have been possessed of an original store of heat previous to condensation." As he says, it may have been its heat that was the very cause of its condition of separation.* If we ask how the nebula came into its dissociated condition, we shall only be doing what the physicists themselves would do in any other physical question, that is, endeavouring to trace backwards the steps of physical causation as far as possible. The moment of rotation possessed by the solar system, as a whole, shows that the original nebula did not start simply with the potential energy of the mutual gravitation of its parts. Its moment of rotation can only have been acquired through its external relations with other masses, or through the operation of forces acting from without. This is quantitatively quite insignificant in itself, comparatively speaking; and if it were the full result of the action that produced it, it would be of very slight importance. But it is very improbable that it is no more than this: It is an indication that there has been an external action on the solar system nebula, the nature of which is unknown; and this opens the door to vast possibilities as to the amount of thermal energy that may have been produced by that action, and been available for lengthening geological time. Dr. Croll has suggested that the solar system nebula may have been formed by the enormous amount of heat that would be produced by the collision of two sufficient cosmical masses. That such collisions have frequently occurred to cause the sudden blazing forth of new stars can hardly be doubted. The spectroscopic indications seem to show that it was something of this kind, on a small scale, that caused the sudden temporary increase of the star in Cygnus that has lately attracted so much attention. Professor Kirkwood has lately given reasons for believing that Sirius and his principal

* Climate and Time, p. 530.

comes may have been originally unconnected bodies whose proper motions brought them near enough to each other so that they became, as it were, entangled into one system. He believes that Sirius may be younger, that is, in a less advanced stage of formation, than our sun. Is it not quite possible that this may be due to collision with a companion of his now subject *comes?* But we must not indulge further in speculation, though, from the nature of the present case, it is perfectly legitimate for us to do so.

In concluding this part of our subject, let us note the data that we must have in order to be able to calculate the amount of heat that there would be to be radiated by the solar system, and the power of radiating that heat. We may neglect the masses of the planets and the chemical energy of separation, both of which, though telling in our favour, are proportionally unimportant.

We know, then, the mass of the original nebula pretty nearly; it is conceded on all hands that the separation of its parts was very great—how great it is not necessary to know, because beyond the magnitude usually contemplated for it, any additional extension, however great, would make very little difference in its potential energy. We know the unit of gravitation attraction. We know the mechanical equivalent of heat. But that is all. We are not in possession of the other essential elements of the question. We do not know the mode of distribution of mass in the original nebula. We do not know what critical points may intervene between the original and the present states of aggregation of the materials. We do not know what were, and are, the thermal capacities of the materials under the varying conditions of aggregation, temperature, and pressure. We do not know what were their radiating powers under those changing conditions. We do not know what operations may have come into play to interfere with their radiation; one has been mentioned already. We do not know that the mutual gravitation of the parts of the nebula was the sole bond of union between them, and was the sole force that was to cause, and to regulate the rate of, the evolution of that part of the heat that was originally potential. Prof. Tait, himself, alludes to this, *op. cit.* p. 153. Under what are, relatively to our very limited knowledge, extreme physical conditions, such as those of the original nebula

and of the present sun, physical laws often emerge into view, and sometimes even into being which before were unsuspected.

The estimates given of the amount of potential heat in the solar system nebula are exceedingly interesting and suggestive; they are very instructive as illustrations of certain ascertained principles and undeniable mathematical relations; but as demonstrations of the past and present circumstances and actualities of the solar system they must be, at any rate, very uncertain, and may be, for all we can tell, considerably wide of the mark.

B.—The next argument we have to notice is that drawn from the shape of the earth in connexion with her present rate of rotation. Our globe is an oblate spheroid in consequence of the centrifugal force ot rotation; and if she were fluid, and the law of increase of density, in descending towards the centre, were known, it would be possible to calculate what would be the spheroidicity due to her rate of rotation. Now the actual spheroidicity of the earth, taken as a whole, agrees pretty nearly with that calculated on a reasonably assumed law of increase of density. A few years ago the only conclusion that could be drawn from this was that the supposed, must agree fairly well with the actual, variation of density. But two striking discoveries arrived at in late years have made this agreement very important in a different way altogether. Delaunay has pointed out (originally, as regards himself, though it had been already suggested by Kant) that the earth's rate of rotation must be diminishing, from the action of the ocean tides; and that consequently the amount of her spheroidicity, also, must be lessening, supposing her to be fluid. But Sir William Thomson has concluded that the earth must be, as a whole, about as rigid as continuous steel; and he argues that as the earth's shape is nearly that corresponding to her present rate of rotation, she must have become rigid when her rotation rate was but little higher than it now is, that is to say, a comparatively short while back. Prof. Tait believes that this argument, taken along with that which we have yet to consider, reduces geological time to something less than ten millions of years.

The following may be urged in reply. In the first place, granting that the earth is as rigid as steel (when tested as Sir William tests her), she will still, as he calculates, yield to the

tidal deforming action one third as much as if composed of water. He has in view *equilibrium tide* deformation. But the centrifugal deformation and the other are similar as regards the present matter, so that we can now argue from one to the other; therefore the earth, though rigid as steel, will yield to the centrifugal force, or to any change of it, one third as much as if she were all water: so that only two-thirds of our difficulty remains to be removed. Dr. Croll has doubtless removed part of this remainder by the suggestion that the denuding agencies would tend to distribute detrital matter so that its surface would be everywhere nearly perpendicular to the direction of the resultant of gravitation and the centrifugal force, and that in this way the shape of the earth would always nearly correspond to the actual amount of its diminishing centrifugal force. He also points out that the removal of material, from the equatorial towards the polar regions of the more slowly rotating earth would further help our cause by tending to delay the retardation of the earth's rotation. Though the amount of relief thus afforded us is probably quite small, still we must not neglect it.

Let us consider more closely this steel rigidity of our globe, which we do not presume to question, though the evidence for it, as Sir W. Thomson himself shews, now rests only upon the lunar fortnightly declinational, and the monthly elliptic, tides. There are different species of rigidity. Although our globe be practically as rigid and uncomplying as steel, relatively to the straining forces by which Sir William has tested her, she may nevertheless be as compliant as need be, relatively to the action with which we are now engaged.

The peculiar character of viscous rigidity is well known. Perhaps the most familiar and most apt illustration of it is afforded by a stick of sealing-wax at an ordinary mean temperature. If we subject such a stick for a short time to a considerable transverse pressure, sufficiently below that which would cause fracture, no perceptible impression will be made thereon; and if that considerable pressure be a reciprocating one of short period, it may be continued for ever with as little effect. But if the same stick of sealing-wax be subjected to a very much smaller pressure, having always the same direction and continued for a very long time, it will give way thereto as a quite soft body

might do, in a short time, under the same small straining force. If the stick be supported at both ends and left so for several weeks, its own mere weight will be sufficient to make it bend downwards considerably in the middle. And yet while thus really a fluid it is all the time exceedingly hard, and if broken will snap with a conchoidal fracture, which is generally characteristic of hard and close substances. Now we seem to have good reason to believe that our globe, taken as a whole, is a viscous body in this sense; and therefore, though she be practically as rigid as steel, relatively to the cycling, reciprocating, comparatively short-period tidal forces called the lunar semi-monthly declinational, and the monthly elliptic or parallactic, yet she may be very different indeed, relatively to the continued ever similarly directed decrement of the centrifugal force of rotation, which, relatively to the present matter, is equivalent to a positive deforming force.

Let us, then, see what reasons there are for believing our earth to be, as a whole, a viscous body. The explanation of viscosity given by Clerk Maxwell is, very briefly, somewhat as follows. Even in homogeneous and solid bodies, whose molecules have thermal agitation, the groups of molecules are not all similarly conditioned. The agitation of the molecules of particular groups may accumulate, so that ever and anon the configuration of a group will break up, and, if the body is under strain, take a new configuration, which will be adapted to the present relative positions of the groups and free from strain. The tendency to do this depends partly on the amplitude of the heat oscillations, and partly on the amount of strain. If there are a sufficient number of groups disseminated through the body which are stable under the conditions, the substance will be a solid with a limited amount of viscosity, which all bodies have; and if all the groups or only the great majority of them can, one by one, behave as we have described, the body will be a viscous one.

Let us now, without making others responsible, consider the probable conditions of a body at a far higher temperature than that of *free* uncompressed fusion, and yet kept solid by tremendous pressure. (Sir William still contemplates the concession to us of about 7000° F. as the temperature of the interior of the earth.) The amplitude of the oscillations of the molecules is now vastly greater than was possible under unenforced solidity. But

the strong compression keeps the body still apparently quite rigid when tested by short-period straining forces. But as the two rigidities depend upon very different conditions, they must be, in all probability, very different in kind. The former depended alone on the substantive cohesion of the particles and the (interfering) heat oscillations; the latter on the new strength of cohesion, to which the compression gives rise, and to the far more violent heat oscillations.

The compression has probably but little *direct* effect in producing rigidity. Its principal effect is to enable the attraction of cohesion to have place by the molecules being held together closely enough; the cohesive attraction now depends for its opportunity of acting on the pressure. But that pressure cannot be absolutely uniform among the groups of molecules; it is so *statistically* only (somewhat as in a gas, although the cases are very different); this must be so at any rate, and especially under the interfering jostling action of the excessively violent oscillations; and therefore the cohesion among the molecules, or groups of molecules, cannot be uniform; and if the pressure do not prevail too much over the thermal excitement the variation of cohesion may well be sufficient to make some of the groups of molecules at any instant, and all, or a sufficient proportion of them in turn, unstable under certain amounts of strain—and these are precisely the supposed molecular conditions of a viscous body.

Now when we consider that the mean density of the whole globe is only about double that of its superficial parts, and even that that small increase of density is doubtless partly due to the higher specific gravity of the interior parts, and therefore only partly to the compression, we may conclude that the internal high temperature is largely able to hold its own, as to its loosening tendency, against the increased cohesion resulting from the condensation under the internal pressure. Sir William himself contemplates all the interior parts of the earth being somewhat near the melting points corresponding to the actual pressures. Therefore the great probability seems to be that the rigidity of our globe, though as high in degree as supposed by Sir. W. Thomson, is, as to species, a viscous rigidity, which will answer our purpose quite well. That of the crust is not worth mentioning.

But now we come to what seems to be a satisfactory confirmation of this position. I was myself the more struck by it

because it did not attract my notice until after the above conclusion had been arrived at. Sir William states that though the lunar semi-monthly declinational and monthly elliptic tides, as discussed by the Tidal Committee of the British Association, of which he is a member, indicated either no yielding or more probably a very small yielding of the body of the earth, yet that the absence from all the results of any indication of a 18·6–year tide, connected with the revolution of the moon's nodes, could not be easily explained without assuming or admitting a considerable degree of yielding. If there be no perceptible ocean tide, answering to the unquestionably existing 18·6–year variation of tidal force it shews that the body of the earth and the ocean go together; or so nearly together that the difference is not perceptible. The difference of straining force, connected with the last-mentioned tide, is far less than those connected with the two former, and yet the body of the earth recognises it far more sensibly because of its long period.

Though this fact is to me more striking as a confirmation, in consequence of the order in which it occurred to me, others might prefer to make it a substantive argument and say—If our grandly deliberate globe, which refuses to be hurried and stands sensibly as obstinate as steel to a fortnightly or a monthly change of force,. will, nevertheless, yield considerably to a much smaller 18·6-year change of force, when she has reasonable time given her, what may we not expect of her when she an indefinite length of time in which to accommodate herself to the continued and ever similarly directed decrement of the centrifugal force of rotation?

But, besides, if our earth be, as a whole, a viscous body capable of yielding in this manner there is something to help her to respond, through her viscosity, to a suitable straining force. If a viscous solid is very slowly giving way to a continued gentle pressure the movement is promoted if small, reciprocating agitations, or vibrations, be set up in the yielding mass. Now the semi-diurnal tidal straining of the earth is an action, which, though small in amount, is there, *quantum valeat,* and which is of the kind required to help our viscous globe, as we shall take leave to call it, to answer to the continual decrease of the centrifugal force. Some of the other variations of tidal force which affect our earth may be equally important in this way, on account of their much longer periods, and notwithstanding their smaller amount.

From the nature of the operation, the frequent combination of two or more of these variations of strain, in similar and favourable phases, and their consequent co-operation in producing helping stresses in the body of the earth, must evidently tend to promote further the yielding of the viscous mass, notwithstanding their being accompanied by partial interferences and unfavourable combinations. Perhaps even the greater changes of barometric pressure may be of some assistance. The tidal forces affect our globe to its inmost parts, though of course they diminish in the proportion of the distance from the centre. To these agitations we may add the geological disturbances proper, whatever their cause; though their effect in this respect must be slight. Their primary effect is, doubtless, the production of somewhat local irregularities of the surface; but, taken all together, they must tend to promote the settlement of the globe, as a whole, into its general mean figure of equilibrium.

C.—The last argument, in our order of discussion, for the restriction of geological time, is that the present mean rise of temperature in descending the crust of the earth shows that "about 10,000,000 or (say at most) 15,000,000 of years" ago the surface of the earth had just consolidated. Professor Tait clearly prefers the ten millions; as we see not only from the words quoted, but from others also. Now, Sir William, in his famous paper on the Secular Cooling of the Globe, proposed to give us 100,000,000 years and perhaps much more; probably it is owing to the influence of his sterner coadjutor that he has since cut us down to 90, or even 50. But observe that he still contemplates having to concede 90, that is to say, six times as much as Professor Tait would yield on compulsion, and nine times as much as he would grant willingly. Now, nine to one is rather a high proportion in a case of this kind; and when we note the discrepancy, it is calculated to lessen considerably the anxiety with which we listen to this argument for the restriction of geological time. May we not say, with the most profound respect for these two distinguished coadjutors, that if they had arrived at some consensus between themselves their opinions (for such alone they really are) on this point would have been entitled to greater weight? In a case of so wide divergence it would be delusive to adopt the mean of the results. The question is one of mathematical calculation, founded upon

ascertained physical laws, which, for their applicability to the matter in question, depend themselves upon hypothetical conditions or assumed data; the *a priori* validity of the mathematics and the *a posteriori* validity of the laws sometimes, in a case of this kind, dazzle the eyes of the on-looker, and, by irradiation, spread on his mental retina over the conjoined assumed conditions, and conceal the doubtfulness of *their* validity. And this can happen even to the proposer of the conditions, who may have originally put them forward expressly as only hypothetical, and even as being an acknowledgedly imperfect representation of facts; perhaps, indeed, he is more in danger of this than the on-looker.

We shall find on examination that Sir W. Thomson himself originally intended his paper to be only a contribution to the investigation of the matter founded upon three conditions, which he assumed for convenience and simplification. The data assumed are, first, the uniform or approximately uniform temperature of the body of the earth when it had just solidified; secondly, the conductivity and thermal capacity of the materials of the globe; and thirdly, a certain low and constant temperature of the surface. He gives reasons for believing that the first assumption may be probable; it is unquestionably quite possible, as far as we know at present. But he himself admits, or rather warns us, that the second is a pure assumption; and the third must be an incorrect representation of the case. If one of the three factors which go to produce the result be purely and confessedly hypothetical, it matters little, as far as the immediate question is concerned whether the others be right or not.

As to the *first* of the three conditions, Sir William believes that the materials of the earth nebula may have condensed somewhat regularly round a cold nucleus. The energy of the later part of the nebular, or meteoric rain would be much greater than that of the earlier, and cause a much higher temperature in the outer parts of the globe, but for the interior pressure which may have nearly equalized the temperature by raising it in the inner parts.

We will not now presume to measure swords with Sir William, and to enter upon counter-speculation as to how the materials of the earth-nebula fell together; yet it would not be difficult to

point out various probabilities which would tend in the other direction. According to one mode suggested as that in which the materials of the earth finally fell together, there would be two great reaches of the earth-nebula collapsing *obliquely* into each other, giving rise to tumultuous eddyings in the newly collected and defined mass, which would mingle together to a great extent, different parts thereof with their different temperatures. Another circumstance which would promote such mingling is the difference of specific gravity of the materials after condensation. If this were so, as is exceedingly probable, the enormous condensation in the inner parts of the newly-defined globular mass would liberate a vast amount of heat to raise the temperature of those parts; and, as is evident, any heightening of temperature produced in *this* way would be unaffected by the remains of the eddyings just referred to, and by any convection currents (properly so called); it could itself produce no such currents as is evident. It could only be lowered by what would be really *conduction*, though acting under peculiar circumstances. We should thus have, though not an additional store, yet a more inward disposition or grouping of high temperature, favourable for rendering slower the cooling of the exterior parts of the globe beyond what is contemplated by our opponents, and available, therefore, for lengthening the period of geological time.

If we knew accurately the present law of the increase of temperature per unit of depth, and the actual conditions of conductivity within the earth, supposing both to be approximately uniform round the centre, then the application of Fourier's theorems would enable those competent to use such instruments, to decide whether the internal temperature of the earth at the commencement of geological operations proper was approximately uniform, or whether it increased towards the more inward parts. But the depth to which man has penetrated beneath the surface is utterly insufficient to shew the true law of increase of temperature, even independently of the numerous disturbing conditions at every place of observation. Without such interferences the rise of temperature would be sensibly uniform down to a much greater depth than that of less than half a mile; and that would be so in either case, that is whether the temperature begins to be nearly uniform at a comparatively small depth of not

many scores of miles, as Sir William believes, or whether it continues to increase to a very much greater depth.

To proceed now to the *second* of the three conditions assumed by Sir W. Thomson when calculating the rate of the earth's cooling; viz., the probable heat-transmitting power of the body of the globe, or at least of the more outward parts of the body of the globe. It is our interest to keep this down as much as possible. A more rapid rise of temperature in descending into the earth, to the depth of which man has knowledge, might be due to any of the following circumstances, or to some of them conjointly:—1. The shortness of the time of cooling of the earth. 2. The lower conductivity of the rocks to that depth, as compared with surface rocks. 3. The higher conductivity of the rocks below that depth. Sir William accounts for the rapid rise of underground temperature, in depth, by the first of these, the shortness of the earth's cooling period. We would submit that the second, also, may be concerned; if it be so, the argument for the first is weakened, which is all that we desire. It is of relatively small importance to us whether the third obtain or not.

Sir William, in order to have something to go upon, has assumed (not that he believes it) the absolute thermal conductivity and the thermal capacity of the globe to be that of average surface rocks. At first sight it might seem probable that this may not be much beside the mark, for there are two principal influences which tend in opposite directions in their effect on the result. The tendency of the rise of temperature which obtains as we go down is, *cæteris paribus*, to diminish the heat transmitting powers of the materials below. The tendency of the increase of density is to increase the heat transmitting powers of those materials. Do these opposing tendencies probably balance each other approximately? or, if not, which of the two more probably prevails over the other?

Of course we now move with very great caution, remembering that in such a question as this, we cannot argue positively from what has been ascertained merely within the limited range of conditions accessible to the physicist in his laboratory. As Sir William himself says "we are very ignorant of the effects of high temperatures in altering the conductivities and specific heats of rocks, and as to their latent heat of fusion." But the

circumstance just referred to makes it now more than usually allowable to argue from experiments under limited ranges of condition. Sir William declares that he believes it likely that the materials of the globe, though on the whole as rigid as steel, may be yet, at every depth, not much below the melting temperature corresponding to the pressure at that depth. If this should be so it would tend to make the effects of the increasing temperature and of the increasing pressure to be generally comparable with each other. Though the two influences concerned are each of high intensity, according to our ideas, as they are opposed, and perhaps somewhat near a balance in a certain respect, they may produce, as regards this, a mean result which is probably accordant with physical laws, in forms not very different from those manifested by them under the nearest laboratory conditions. To this we may add that the critical point of fusion and the consideration of its latent heat is happily avoided. But for these two circumstances it would be hardly worth while to enter on the following argument.

Within the range of experiment the general law seems to be that, with rise of temperature, the absolute conductivities of substances diminish,* and their thermal capacities increase, so that, for a two-fold reason, when the temperature of a body is raised its power to transmit *diminishing* heat becomes lessened. On the other hand increase of pressure, as a general rule, acts in the opposite way; it causes the absolute conductivities of substances to increase, and their thermal capacities to diminish. But before proceeding further let us note that, with metals at least, even if the condensation due to high pressure be equal to the expansion due to increased intensity of heat the thermal conductivity will still be diminished. So that if the density of such substances remains unaltered, the high temperature, though only just a match for the high pressure, as far as its effect on density is concerned, is more than a match for the high pressure in diminishing the heat-transmitting power of such substances.

Now let us note a circumstance that adds to the importance in the present question of elevation of temperature. The rate of expansion of heated bodies increases with the rise of temperature; this goes to promote the diminution of the thermal conductivity

* See note at end.

of the materials of the earth, considered solely with reference to their heightened temperature.

Now, on the other hand, there are two circumstances which tend to lessen further the importance of increase of pressure. The first is that, although small diminutions of the volume of solids under pressure and consequent increments of density are sensibly proportional to the pressures, yet the rate of compression will fall off with a very great augmentation of pressure. The second is, that the very increase of density actually helps the thermal expansion to work against itself; for if the density of a body has been increased by some means, the general rule is, that the rate at which it expands with rise of temperature is also increased. So here are two circumstances which go to lessen the tendency which the pressure at considerable depths has to increase the heat-transmitting powers of the materials of the cooling globe.

Therefore, then, besides the fact that laboratory experiments are already encouraging to us, there is the great probability that the power that the high temperature of the interior of the globe has to promote our interests as geologists is greater, and the opposing power of the high pressure is less, than what might be concluded, on first thoughts, from such experiments, carried out under necessarily limited variations of condition.

But these considerations, though auxiliary, are only such.—Can we form any rough conjecture, on other grounds, as to the actual relations of the two contending influences within the body of the earth? When we consider the enormous pressure that must exist within the globe, it is surprising to find that the mean density of the globe is only about double that of the mean density of its superficial parts (disregarding the thin film of ocean.) This formerly induced some persons, who were neglecting all other considerations, to believe that the inner part of the earth must be hollow. The difficulty felt by those persons would have been greatly increased on being informed by the astronomers, that certain peculiarities in the motion of the moon, both in latitude and longitude, shew that the attracting spheroidal earth must be much denser in the central parts than elsewhere. This is confirmed by other considerations. This goes to keep down the density of the less inward parts (the mean density being

given) and to make it highly probable that the increasing temperature is more than able to hold its own against the increasing pressure, as far as diminishing the conductivity of the less inward parts is concerned. The above "auxiliary considerations" shew that is not necessary for our purpose that the increased temperature should be a match for the increased pressure, as regards the *condensation* produced thereby. This it probably is not. And yet we must not concede too much even on this point. It is a very reasonable belief that the unquestionable high density of the more inward parts of our earth is partly due to the greater specific gravity of the materials there—that is to say, for all that appears to the contrary, the expansive power of the heat may, even there, be a match for the condensing power of the pressure, which, however, we do not wish it to be. However, as regards the present question we may be indifferent as to the thermal conductivity of the more inward parts if, as seems so very probable, we have a sufficient thickness of material of lowered conductivity between it and the surface. Its comparatively small magnitude, also, makes it of little importance.

It would be very interesting to know more than we do on the thermal expansibilities and the compressibilities of rocks. It would enable us to form some sort of opinion as to how the conductivity of the geological crust is affected by the conflicting heat and pressure to which it is subject. It is, however, worth while to mention that iron. copper, and slate, under the conditions of heat and pressure which must obtain for a few miles, at least, beneath the surface, would be in a more expanded state than at the surface; that is to say, their thermal conductivities would decrease with the increase of depth. As slate has been produced under enormous pressure, the effect of which it still retains in its high density, its behaviour as regards expansion by heat and condensation by (further, artificial) pressure is very significant and important, as regards the present matter. It should be acknowledged that marble would probably become more condensed when subjected to the conditions that exist for some distance beneath the surface.

We now pass to another consideration which is essentially unconnected with what we have just been considering, but which tends in the same direction. Sir William Thomson, in forming

his estimate of the conductivity of surface rocks, availed himself of the observations made upon the rocks of Calton Hill, Edinburgh. By calculation applied to the results of observation, he determined the thermal conductivity of those rocks while still lying *in situ*, in their natural conditions. Supposing the observations to be fairly free from disturbing circumstances, this is probably the best mode of investigating this subject. Another mode has been followed by the Committee of the British Association appointed for this purpose*, which has its own advantages and peculiar capabilities. They have instituted a valuable series of laboratory experiments on specimens of various rocks. One of their results, which could not be otherwise obtained, is that the conductivity of any particular rock, when thoroughly dry, is considerably less than its conductivity when moist. Now, accessible rocks, when we have penetrated a very small depth beneath their surface, are moist; stone when just quarried is, as the stonemason expresses it, "green;" but the great probability is that at a sufficient depth the rocks are dry. We are not now ignoring the water concerned in volcanic eruptions, and that which, doubtless, was engaged in metamorphism. It is a common belief that it is the internal heat of our earth that keeps the water of the earth at, and comparatively near, the surface, and that when our earth has cooled down, as the moon evidently has done, that her water will sink down into the crust, as has most probably happened already with the moon. Here, then, is another circumstance which would make, *cæteris paribus*, the heated rocks at a sufficient depth to be worse conductors of heat than those at the surface.

Thus, then, if we may form an opinion from our limited means of judging, the great probability seems to be that the decrease of conductivity, owing to the high temperature, and also to the dryness of the interior rocks, exceeds the increase thereof due to the greater density produced by pressure, and that, therefore, [the conductivity of the interior, neglecting the more inward, probably metallic part, is less than that of the superficial parts, which was assumed for it by Sir William Thomson.

We now come to the *third* of the three conditions assumed by Sir William when calculating the rate of the earth's cooling. The

* Brit. Assoc. Rept., 1877.

objection pointed out by Professor Huxley seems to be sufficiently obvious to make it common property. Sir William, in order to apply his mathematical calculation to the cooling earth, was obliged, as we have said, to make some assumption as to the difference of temperature between the interior and the surface of the globe, and to suppose that of the surface to be constant. But physical considerations show that there must have been a great cloud covering round the earth during the time of her own higher temperature, and caused thereby. (Professor Tait mentions that such would have been caused by the sun's greater radiation.) Geological phenomena lead to the conclusion that there must have been, formerly, a much greater uniformity of climate over the globe than what now obtains; this also points to the universal cloud covering as its easiest explanation. It is unnecessary to observe what a very great effect this must have had in retarding radiation from the earth. We constantly have most striking evidence of this on nights which are at one hour clear, and at another clouded. Therefore, then we have various and strong reasons for believing that the rate of cooling of the globe has been considerably slower than Sir William estimates, and that therefore the restriction of the length of geological time, on that ground, is probably very much less than he contemplates; how much less it is impossible to conjecture.

May we not, then, venture to maintain with the utmost deference that the argument for what we regard as the very inconvenient restriction of geological time is not proved? From the nature of the case, this is sufficient for our purpose. We have strong positive reasons for believing in the great extent of the geological period; and therefore we are not called upon to absolutely disprove arguments against it which, of necessity, rest largely upon assumption. We contend that we have a logical right even to invert the order of ratiocination, and to argue from the strength of our conclusions, founded upon observation, to the weakness of largely hypothetical considerations, if they be opposed to them.

NOTE.—On March 8, shortly after this paper was read, Professor Tait communicated a paper to the Royal Society of Edinburgh, in which he showed that, contrary to the usual belief no pure metal on which he has experimented (except iron) diminishes in thermal conductivity with rise of temperature. But our argument from thermal capacity is quite unaffected by this.

II.—ON THE TOTAL ANNUAL HEAT RECEIVED AT EACH POINT OF THE EARTH'S SURFACE FROM THE SUN, AND ON THE AMOUNT OF THE LOSS OF THAT HEAT CAUSED BY RADIATION INTO SPACE (NEGLECTING THE EFFECT OF THE ATMOSPHERE),

BY

The Rev. SAMUEL HAUGHTON, M.D., DUBL., D.C.L., OXON.

[Read March 18th, 1878.]

THE heat received by a given surface at any instant is

$$A \cos z \, dh,$$

where

$$A = \text{a known constant},$$
$$z = \text{sun's zenith distance},$$
$$h = \text{sun's hour angle},$$

and

$$\textit{Total heat received in one day} = A \int_{\text{Sunset}}^{\text{Sunrise}} \cos z \, dh, \qquad (1)$$

Now, we have

$$\cos z = \sin \lambda \sin \delta + \cos \lambda \cos \delta \cos h,$$

where

$$\lambda = \text{latitude of place},$$
$$\delta = \text{sun's declination},$$
$$H = \text{hour of sunset}.$$

Equation (1) thus becomes—

$$\text{Total heat received in one day} = \int_{-H}^{+H} \cos z \, dh$$

$$= \int_{-H}^{+H} A \sin \lambda \sin \delta dh + \int_{-H}^{+H} A \cos \lambda \cos \delta \cos h \, dh,$$

$$= 2 A \{\sin \lambda \sin \delta \cdot H + \cos \lambda \cos \delta \sin H\}. \qquad (2)$$

But, since

$$\cos H = - \tan \lambda \tan \delta,$$

the expression (2) may be thus written:

$$\text{Total heat received in one day} = 2 A \sin \lambda \sin \delta \{H - \tan H\}. \qquad (3)$$

This expression might be expanded by means of Leibnitz' theorem, as follows:

$$\text{Total heat received in one day}$$
$$= 2 A \sin \lambda \sin \delta \left(\frac{\tan^3 H}{3} - \frac{\tan^5 H}{5} + \frac{\tan^7 H}{7} - \&c. \right)$$

But this would not answer for calculation, as H passes through 90°, at the time of the equinoxes, when $\tan H$ becomes infinite and $\sin\delta$ vanishes. I therefore expand in terms of $\cos H$ as follows:

$$H = \frac{\pi}{2} - \left\{ \cos H + \frac{1}{2}\cdot\frac{\cos^3 H}{3} + \frac{1\cdot 3}{2\cdot 4}\cdot\frac{\cos^5 H}{5} + \frac{1\cdot 3\cdot 5}{2\cdot 4\cdot 6}\cdot\frac{\cos^7 H}{7} + \&c. \right. \qquad (5)$$

and,

$$\tan H = \frac{\sqrt{1-\cos^2 H}}{\cos H}$$

$$= \frac{1}{\cos H}\left\{ 1 - \frac{\cos^2 H}{2} - \frac{1}{1\cdot 2}\cdot\frac{\cos^4 H}{2^2} - \frac{1\cdot 3}{1\cdot 2\cdot 3}\cdot\frac{\cos^6 H}{2^3} - \frac{1\cdot 3\cdot 5}{1\cdot 2\cdot 3\cdot 4}\cdot\frac{\cos^8 H}{2^4} - \&c. \right. \qquad (6)$$

Therefore,

$$H - \tan H = \frac{\pi}{2} - \frac{1}{\cos H} - \frac{1}{2}\cos H - \frac{1}{24}\cos^3 H - \frac{1}{80}\cos^5 H - \frac{5}{896}\cos^7 H - \&c. \qquad (7)$$

But,

$$\cos H = -\tan\lambda\tan\delta = -\frac{\tan\lambda\sin\delta}{\sqrt{1-\sin^2\delta}}$$

$$= -\frac{\sin\lambda\sin\delta}{\cos\lambda}\left\{ 1 + \frac{\sin^2\delta}{2} + \frac{1\cdot 3}{1\cdot 2}\cdot\frac{\sin^4\delta}{2^2} + \frac{1\cdot 3\cdot 5}{1\cdot 2\cdot 3}\cdot\frac{\sin^6\delta}{2^3} + \frac{1\cdot 3\cdot 5\cdot 7}{1\cdot 2\cdot 3\cdot 4}\cdot\frac{\sin^8\delta}{2^4} + \&c \right\} \qquad (8)$$

and

$$\frac{1}{\cos H} = -\frac{\cos\lambda}{\sin\lambda\sin\delta}\left\{ 1 - \frac{\sin^2\delta}{2} - \frac{1}{1\cdot 2}\cdot\frac{\sin^4\delta}{2^2} - \frac{1\cdot 3}{1\cdot 2\cdot 3}\cdot\frac{\sin^6\delta}{2^3} - \frac{1\cdot 3\cdot 5}{1\cdot 2\cdot 3\cdot 4}\cdot\frac{\sin^8\delta}{2^4} - \&c. \right\} \qquad (9)$$

Hence, finally,

The heat received in one day $= 2A\sin\lambda\sin\delta\,(H - \tan H)$

$$= 2A\left|\begin{array}{l} \frac{\pi}{2}\sin\lambda\sin\delta \\ + \cos\lambda\left\{1 - \frac{\sin^2\delta}{2} - \frac{1}{1\cdot 2}\cdot\frac{\sin^4\delta}{2^2} - \frac{1\cdot 3}{1\cdot 2\cdot 3}\cdot\frac{\sin^6\delta}{2^3} - \&c.\right. \\ + \frac{\sin^2\lambda\sin^2\delta}{2\cos\lambda}\left\{1 + \frac{\sin^2\delta}{2} + \frac{1\cdot 3}{1\cdot 2}\cdot\frac{\sin^4\delta}{2^2} + \&c.\right. \\ + \frac{\sin^4\lambda\sin^4\delta}{24\cos^3\lambda}\left\{1 + \frac{3}{2}\sin^2\delta + \&c.\right. \\ + \frac{\sin^6\lambda\sin^6\delta}{80\cos^5\lambda}\left\{1 + \&c.\right. \end{array}\right\} \qquad (10)$$

Or, since

$$\sin \delta = \sin \Delta \sin l,$$

where

$$\Delta = \text{obliquity of ecliptic,}$$
$$l = \text{sun's longitude,}$$

$$-2A\left[\begin{array}{l} \frac{\pi}{2} \sin\lambda \sin\Delta \cdot \sin l \\ + \cos\lambda \left\{1 - \frac{\sin^2\Delta}{4}(1 - \cos 2l) - \frac{\sin^4\Delta}{64}(3 - 4\cos 2l + \cos 4l) - \right. \\ \qquad \left. \frac{\sin^6\Delta}{512}(10 - 15\cos 2l + 6\cos 4l - \cos 6l) - \&c. \right. \\ + \tan\lambda \sin\lambda \left\{\frac{\sin^2\Delta}{4}(1 - \cos 2l) + \frac{\sin^4\Delta}{32}(3 - 4\cos 2l + \cos 4l) + \right. \\ \qquad \left. \frac{3\sin^6\Delta}{512}(10 - 4\cos 2l + 6\cos 4l - \cos 6l) + \&c. \right. \\ + \tan^3\lambda \sin\lambda \left\{\frac{\sin^4\Delta}{192}(3 - 4\cos 2l + \cos 4l) + \frac{\sin^6\Delta}{512}(10 - \&c.) + \&c. \right. \\ + \tan^5\lambda \sin\lambda \left\{\frac{\sin^6\Delta}{2560}(10 - \&c.) + \&c. \right. \\ + \&c. \end{array}\right] \quad (11)$$

We must now substitute for l the sun's longitude, on each day of the year, and add the 365 terms together; this will convert all the periodic terms of (11) into the sums of sines and cosines of arcs in arithmetical progression taken all round the circumference, and with a very small common difference.*

The periodic terms, therefore, vanish in the summation, and we obtain,

$$\text{The heat received in one year} = 2A \sin\lambda \Sigma \sin\delta(H - \tan H)$$

$$= 2A \times 365{\cdot}25 \left[\begin{array}{l} \cos\lambda \left\{1 - \frac{\sin^2\Delta}{4} - \frac{3\sin^4\Delta}{64} - \frac{5\sin^6\Delta}{256} - \&c. \right. \\ + \tan\lambda \sin\lambda \left\{\frac{\sin^2\Delta}{4} + \frac{3\sin^4\Delta}{32} + \frac{15\sin^6\Delta}{256} + \&c. \right. \\ + \tan^3\lambda \sin\lambda \left\{\frac{\sin^4\Delta}{64} + \frac{5\sin^6\Delta}{256} + \&c. \right. \\ + \tan^5\lambda \sin\lambda \left\{\frac{\sin^6\Delta}{256} + \&c. \right. \\ + \&c., \&c. \end{array}\right] \quad (12)$$

Substituting for Δ its value, 23° 28′, we obtain, finally,

* Equal to 59′ 8″ (the daily change in sun's longitude), or small multiples of that arc.

Total heat received in one year

$$= 2A \times 365{\cdot}25 \left| \begin{array}{l} 0{\cdot}95910 \cos\lambda \\ \quad + 0{\cdot}04187 \tan\lambda \sin\lambda \\ \quad\quad + 0{\cdot}00047 \tan^3\lambda \sin\lambda \\ \quad\quad\quad + 0{\cdot}000015 \tan^5\lambda \sin\lambda \\ \quad\quad\quad\quad + \&c. \end{array} \right\} \quad (13)$$

It is evident, from this equation, that when the latitude is small, the heat received in the year varies as the cosine of the latitude.

It is to be observed that equation (3), which expresses the heat received in one day, becomes illusory inside the arctic and antarctic circles, when the sun does not set; for then H (the hour of sunset) has an imaginary value. We must, therefore, compute the annual heat received inside these circles by summing the heat from the equinox till the time when the sun does not set or does not rise by equation (12); and adding the heat received during the time when the sun does not set.

If D denote the sun's declination, when he ceases to rise or set, equation (12), with D substituted for Δ, will give the heat received during the part of the year when the sun rises and sets, and the angle H is real.

To this must be added the heat received during the time when the sun never sets, which may be found as follows:

Referring to equations (1) and (2), we have, when the sun does not set,

Total heat in one day

$$= A\int_0^{2\pi} \cos z\, dh \qquad (14)$$

$$= A\int_0^{2\pi} \sin\lambda\ \sin\delta\, dh + A\int_0^{2\pi} \cos\lambda\ \cos\delta\ \cos h\, dh,$$

$$= 2A\pi \sin\lambda \sin\delta = 2A\pi \sin\lambda \sin\Delta \sin l.$$

This value must be summed through the time that the sun does not set; or, if α be the daily change in sun's longitude,

The total heat received during the time that the sun never sets

$$= 2A\pi \sin\lambda \sin\Delta\ \{\sin l + \sin(l+\alpha) + \sin(l+2\alpha)\} + \&c. \qquad (15)$$

$$= 2A\cdot\pi \sin\lambda \sin \frac{\sin\left(l + \frac{n-1}{2}\alpha\right)\sin\frac{n\alpha}{2}}{\sin\frac{\alpha}{2}};$$

where

$$\sin l = \frac{\sin D}{\sin \Delta},$$

and

n = number of days during which the sun does not set,

and

$a = 59' \, 8''$.

But it is evident that

$$l + \frac{n-1}{2} \imath = 90° \quad q.p.;$$

and, therefore, (15) reduces to the following expression :—

$$\left.\begin{array}{r}\text{Total heat received during the}\\ \text{time that the sun never sets}\end{array}\right\} = 2A \cdot \pi \sin \lambda \sin \Delta \cdot \left(\frac{\sin \frac{na}{2}}{\sin \frac{a}{2}} \right) \qquad (16)$$

At the Pole itself, since the sun never sets, this expression, summed for half a year, gives the total heat received.

If we calculate from the Equator to the Arctic and Antarctic Circles, by equation (13), and from thence to the Poles, by equations (12) (with D for Δ) and (14), we obtain the following Table :—

TABLE showing the TOTAL HEAT received by various Latitudes from the Sun in the course of a Year.

Latitude.	Feet of Ice melted.	$\frac{A \cos \lambda}{\text{Feet of Ice.}}$	Difference.
0°	97·8	97·8	0·0
10	96·5	96·3	0·2
20	92·4	91·9	0·5
* 23 28′	86·7	—	—
30	85·9	84·7	1·2
40	77·3	74·9	2·4
50	66·8	62·9	3·9
† 52 30′	61·4	—	—
60	55·7	48·9	6·8
‡ 66 32′	46·6	—	—
70	46·3	33·4	12·9
80	41·9	17·0	24·9
90	40·5	0·0	40·5

The average thickness of ice melted over the entire surface of the globe (allowing for the greater areas of the lower latitudes), by the annual sun-heat, as deduced from the foregoing figures, is exactly 80 feet.

* Tropics of Cancer and Capricorn.
† Mean Latitude of Ireland.
‡ Arctic and Antarctic Circles

The foregoing Table is constructed on the supposition that equal quantities of sun-heat are absorbed by the atmosphere at all zenith distances; but, although this supposition is only a first approximation, yet by comparing the total quantities of sun-heat at each latitude with the following Table of Mean Annual Temperatures, some valuable conclusions may be drawn relative to the absolute radiation of heat into space from the earth's surface regarded as a whole.

MEAN ANNUAL TEMPERATURES.*

South Latitudes.	Temperature.	North Latitudes.	Temperature.
°	°	°	°
0	80·1 F.	0	80·1 F.
10	78·7 „	10	81·0 „
20	74·7 „	20	77·6 „
30	66·7 „	30	67·6 „
40	57·9 „	40	56·5 „
50	47·8 „	50	43·4 „
60	35·3 „	60	29·3 „
		70	14·4 „
		80	4·5 „

Let

T = annual sun-heat at a given latitude measured in feet of ice;
θ = mean annual temperature of a given latitude;
k = an unknown coefficient;
R = unknown radiation into space at that latitude.

Assuming that θ, the mean annual temperature of a given parallel of latitude, is proportional to the heat *retained*, we have—

T = total heat *received;*
$k\theta$ = heat *retained;*
R = heat *lost* by radiation;

and, therefore,

$$T = k\theta + R.$$

* W. Ferrel, United States Coast Survey. "Meteorological Researches," Part I., 1877.

This gives us, in the Southern Hemisphere, the following seven equations:—

0° . . .	$97{\cdot}8 = 80{\cdot}1\,k + R.$	(1)
10 . . .	$96{\cdot}5 = 78{\cdot}7\,k + R.$	(2)
20 . . .	$92{\cdot}4 = 74{\cdot}7\,k + R.$	(3)
30 . . .	$85{\cdot}9 = 66{\cdot}7\,k + R.$	(4)
40 . . .	$77{\cdot}3 = 57{\cdot}9\,k + R.$	(5)
50 . . .	$66{\cdot}8 = 47{\cdot}8\,k + R.$	(6)
60 . . .	$55{\cdot}7 = 35{\cdot}3\,k + R.$	(7)

Any two of these equations will determine k and R; and hence we have 21 combinations for finding their values.

These all give consistent results, and the mean values of k and R, derived from the 21 combinations, are—

$$k = 0{\cdot}8995.$$
$$R = 22{\cdot}405 \text{ feet of ice.}$$

As the distribution of heat near the equator is disturbed by the motions of the heated water, so that the parallel of 10° N. is actually hotter than the equator, I have made another calculation, throwing out the latitudes 0° and 10°, which reduces the combinations (from latitudes 20° to 60°) to 10 in number. The result of this calculation is—

$$K = 0{\cdot}8512.$$
$$R = 22{\cdot}60 \text{ feet of ice.}$$

The agreement of these results with the former shows that our formula represents well the whole of the Southern Hemisphere, whose annual radiation of heat may be represented by 22 feet of ice melted.

In the Northern Hemisphere we have the following nine equations—

0° . . .	$97{\cdot}8 = 80{\cdot}1\,k + R.$	(1)
10 . . .	$96{\cdot}5 = 81{\cdot}0\,k + R.$	(2)
20 . . .	$92{\cdot}4 = 77{\cdot}6\,k + R.$	(3)
30 . . .	$85{\cdot}9 = 67{\cdot}6\,k + R.$	(4)
40 . . .	$77{\cdot}3 = 56{\cdot}5\,k + R.$	(5)
50 . . .	$66{\cdot}8 = 43{\cdot}4\,k + R.$	(6)
60 . . .	$55{\cdot}7 = 29{\cdot}3\,k + R.$	(7)
70 . . .	$46{\cdot}3 = 14{\cdot}4\,k + R.$	(8)
80 . . .	$41{\cdot}9 = 4{\cdot}5\,k + R.$	(9)

These nine equations furnish 36 combinations for finding k and R, and of these, 33 give consistent results; but three combinations, viz.:—

$$(0^\circ - 10^\circ), \quad (0^\circ - 20^\circ), \quad \text{and} \quad (10^\circ - 20^\circ),$$

give results inconsistent with the others, in consequence of the cause already stated. The mean values of k and R deduced from the remaining 33 combinations are—

$$k = 0{\cdot}7285.$$
$$R = 34{\cdot}385 \text{ feet of ice.}$$

If we throw out altogether the latitudes 0° and 10°, and calculate from the remaining 21 combinations (from 20° to 80°), we find—

$$k = 0{\cdot}7141.$$
$$R = 35{\cdot}475 \text{ feet of ice.}$$

The agreement between the results calculated from all latitudes, and those found by omitting the low latitudes, is not quite so close in the Northern as in the Southern Hemisphere; but our formula is fully justified, and we are entitled to conclude that the annual heat lost by radiation in the Northern Hemisphere may be 35 feet of ice melted.

It follows, that the mean annual radiation of heat from the whole earth is equivalent to melt a coating of ice 28·5 feet in thickness; but as the sun-heat received is equivalent to 80 feet of ice, we have 51·5 feet of ice representing heat not accounted for as heat, for the mean temperature of the earth's surface is not increased.

This balance of heat is expended in two ways:—

1. It is converted into the Geological work done by rainfall and rivers.
2. It is converted into Chemical and Vital work done by the vegetable and animal organisms that clothe the surface of the earth.

The Geological work done by rainfall and rivers can be shown to absorb a very small portion of the surplus sun-heat.

The Mechanical work done in crushing to fine powder a cubic foot of rock can be estimated from the following *data*, taken from

the stamps of Polberro Tin Mine. Each stamp weighs 600 lbs. and is lifted and falls through 9 inches 45 times in one minute. Each stamp crushes into fine powder 28 cwt. of tinstuff in twenty-four hours.

Hence,

Work done in crushing one cubic foot of rock . .	= 713·5 ft. tons.

But, we know that the

Work done in melting one cubic foot of ice . .	= 2850·5 ft. tons.

The latter number is almost exactly four times the former, from which I conclude that

The work done in melting one cubic foot of ice would suffice to crush into powder four cubic feet of rock.

It has been shown that the Geological work done by rain and rivers takes 3,090 years to crush and carry to the sea one cubic foot of surface rock; hence we see that one foot of ice (representing sun-heat), would account for the present Geological work of 12,360 years!

III.—ON THE TRIDYMITE-QUARTZTRACHYTE OF TARDREE MOUNTAIN AND ON THE OLIVINEGABBRO OF THE CARLINGFORD MOUNTAINS,

BY

A. VON LASAULX,

Professor of Mineralogy in the University of Breslau. Communicated by Professor HULL, F.R.S.

[Read April 15, 1878.]

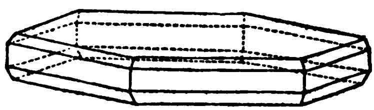
I.

ONE of the most interesting rocks, which I collected during my visit to Ireland in the autumn of 1876, is the Quartztrachyte, of Tardree Mountain, Co. Antrim. This remarkable rock has been well described by Professor E. Hull in the Explanatory Memoir of the Geological Survey to accompany sheets 21, 28, and 29 of the maps. It was formerly described by Portlock, who called it "porphyry of Sandy Brae," also by Berger and Bryce, and has generally been taken for a Quartz-porphyry. It seems unnecessary to enter into a description of its geological occurrence as Professor Hull gives sufficient data to show that this rock is penetrated at the Scolboa Hill by the more recent basalt, and that at other points, for instance the Carnearny Hill and the Tardree Mountain, it is always covered by basaltic flows. Therefore it seems to be the oldest rock of volcanic origin in the County of Antrim.

The petrological characters are the same at the different places which I had occasion to visit. Differences are only based on its colouration and are more or less the consequence of decomposition. In a light gray, yellowish, or light violet paste, of the characteristic roughish condition that gives the name of "Trachyte," to these rocks, are enclosed some rather large crystals of sanidine, more rarely small prisms of a clinoclase, with visible triclinic striation; subangular grains of quartz, sometimes exhibiting more determined dihexaedrons, and rarely minute flakes of a black mica. The sanidine crystals, when fresh, are colourless and glassy; they become white and opaque by decomposition and change into caolinic matter. The quartz is smoky, often almost black. In the very numerous little pores of the rock are to be found groups

of very fine hexagonal tablets of Tridymite,* that volcanic form of silica first detected by Vom Rath† and then found by many others in different volcanic rocks. The hexagonal tablets are partly single, but also occur in groups of two, three and more individuals. Some tablets show on the border of the hexagons small faces of the hexagonal pyramids as represented in figure 1. The tablets are generally covered with a light yellowish crust, due to decomposition of tridymite, and consisting of opal or hyalithlike matter. Very few of the tablets are clear and pellucid.

Fig. 1.



Microscopical Analysis.—The microscopical examination of the rock yielded Sanidine, Clinoclase, Tridymite, Quartz, Biotite, Magnetite, Epidote, Apatite and the microcrystalline paste.

The latter, shows under the microscope a very undeterminate structure, but one can see, principally under crossed Nicols, that it is a very intimate mixture of minute grains of felspar, of quartz and of tridymite. The particles of quartz are always visible by the distinct chromatic polarisation; the tridymite, of which I shall speak afterwards, is not so easily to be detected, but it is found everywhere abundantly in the paste. The structure of the paste is what German petrologists call, with allusion to the paste of the true prophyries "microfelsitic," but has become in many parts already really microcrystalline. I could not find in any part of it, distinct traces of an amorphous or glassy base, only the interspaces of the quartz and felspar are in part of glassy matter. The parallel disposition of the little bands and stripes of the paste give to it here and there a sort of fluidal structure. The sections of sanidine are very clear and transparent when thin. They contain many empty cavities and glassy interspaces with fixed bubbles.

* Professor E. Hull has published the fact of my discovery of Tridymite in this rock in the Journal of the Royal Geological Society of Ireland, 1877, vol. xiv., page 227.

† Poggendorff's Annales cxxxv. 437.

The axis of elasticity, or the direction of the maximum extinction of the light, seen in slices parallel to the plane of symmetry (010; $\infty P \infty$) makes an angle of 11° with the edge between (001) and (010) (the base and the plane of symmetry). The plane of the optical axis is normal to the plane of symmetry, the angle of the optical axis seems not to be the same in all crystals. I found it to be ($2E = 24° 30'$.)

The clinoclase (triclinic felspar) is likewise clear and pellucid. In the sections it forms smaller but longer prisms, with a very beautiful chromatic striation of its twin lamellæ. The angle between the direction of maximum extinction of light and the limiting line of the lamellæ measured in one case 5½° on both sides. In little pieces obtained by cleavage parallel to the base, I found the angle between the edge (001) : (010) and the direction of maximum extinction=2½°. Therefore, according to the determination of the optical properties of the different varieties of felspar by Descloizeaux,* the clinoclase in the present instance is probably a variety of andesine.

The tridymite in the thin sections is easiest found in the places where a little cavity is cut through. In these many of the little hexagonal tablets or fragments of them appear. In the paste it is not so easy to find it, because its absolutely colourless behaviour makes it disappear between the other constituent minerals. There it forms the characteristic tile-like aggregations, first of all described by Zirkel, and then found in many rocks. To see it, it seems useful to change the position of the tube, screwing it higher and deeper, adapting a high magnifying power. Examining some of the largest hexagonal tablets of tridymite in the cavities, under crossed Nicols, I made the observation that they do not remain, when turning them in the plane of the object, dark, as should be the case, if they were hexagonal and uniaxial, but that they show a maximum of light and extinction four times. In the very thin tablets the difference between light and dark is not very great, but always very observable. Also the tablets show that they have not equal optical orientation in every part of a tablet; I did not find one of them of a simple behaviour in that point. Some of them are composed of light and dark places in a somewhat chess-board-like

* Comptes rendus 1875, lxxx. 364-371 and 1876, lxxxii. 1017-1022.

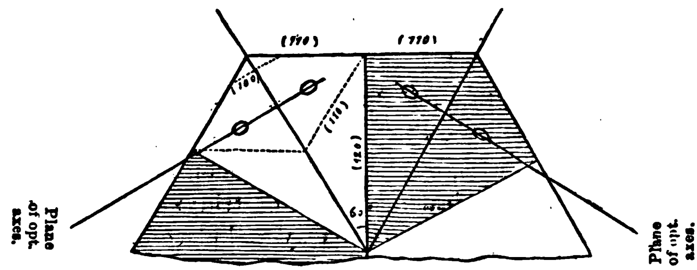
manner, others show distinctly a different orientation of the sextants. The directions of maximum extinction of light make various angles in the different parts of one tablet. The superposition of very thin tablets turned one over another about the vertical axis, causes some uncertainty in the definition of those angles.

The very thin and partly altered tablets of the Tardree Mountain specimens are not well suited to the precise investigation of their optical properties, but because it was on these crystals that I first stated the optical anomalies of tridymite, some further investigations on the same subject may find place here. The very clear and relatively great tablets of tridymite of the Trachyte of the Perlenhardt in the Siebengeberge, near Bonn, on the Rhine, gave me very precise results, and prove that the tridymite is not hexagonal and uniaxial, but distinctly biaxial. I am able to render the interference figure visible in the polarising microscope with all the sharpness that can be desired. One can see the two black hyperbolas marking the poles of the optical axis. The axial angle must be large as the hyperbolas are far apart. The minuteness of the objects have not yet permitted an exact measurement of the axial angle. The plane of the axis seems to be normal to the hexagonal base of the tablets; its intersection with it joins two alternating edges of the base. The direction of maximum extinction bisects the angle of the edges. In some tablets, combined of different parts, the phenomenon appears almost as represented in figure 2, which is diagrammatic. As the plane of the optical axis indicates a pinacoidal plane of the crystal and the other direction of maximum extinction, the other pinacoidal plane, normal to the former, the side of the basal hexagon of Tridymite can only be supposed to be formed by the two prismatic sides (110) of two crystals joined with a prismatical plane (120). We have then here a somewhat similar growing together of twin crystals as we know of in aragonite, witherite and millerite, the latter lately described by Descloizeaux;* all twins of the orthorhombic system, presenting a pseudo-hexagonal form. A further investigation of the crystals of tridymite will prove whether all its hexagonal tablets have the same or a similar structure. The

* Neues Jahrb. für Mineralogie 1877, i. p. 42.

definition of the crossed twins of tridymite naturally becomes very complicated and cannot be pursued at large in this place.

Fig. 2.



The quartz appears in the thin slices of the rock in very clear colourless sections, of a roundish or hexagonal form, often irregular by the intruding paste. The glassy interspaces often show di-hexaëdrical forms, with a fixed bubble; the glassy matter filled with needle-like crystallites of a light brownish colour. Fluid cavities seem to be entirely absent. Several quartz sections are surrounded with a very fine granular border only definable under high magnifying powers as an aggregation of minute grains of epidote.

The biotite appears only very rarely as flakes in the slices, with its distinct pleochroism giving light-yellow, brown, and dark-brown colours. Magnetite, often in regular forms of octahëdrons, is distributed through the paste, in some places partly decomposed into a brown oxide of iron, whence the yellow colour of the paste.

Epidote is distributed through the slices abundantly. It appears in some as well-formed little crystals, with definable faces. One crystal has distinctly the form combined by the faces, m (100), t (001), r (101), z (011), n (111). But mostly it occurs in the form of grains and little bands, easily discernable by their light yellow colour and very vivacious chromatic polarisation. The dense aggregations of little grains, which appear as muddy clouds in many parts of the paste, are for the most part epidote. This mineral seems to be everywhere of a secondary orgin.

Crystals of apatite are not very numerous; its long prisms are sometimes broken, and the single members joined in a pearl-like string.

Chemical Analysis.—Mr. E. T. Hardman has already made an analysis of the rock, which has also been printed by Professor E. Hull in the Explanation to sheets 21, 28, 29, page 18 of the Irish Geological Survey. J. Roth in his excellent collection of analysis of rocks also cites* the analysis of Mr. Hardman, and places the rock of Tardree among the liparites. He remarks on the small amount of alumina in the analysis, the proportion of which is shown in the table. It seemed to me useful (principally with regard to Mr. Hardman's opinion, that the felspar—originally a normal orthoclase—was being gradually transformed into a lime felspar) to conduct an analysis of the sanidine, of which it is very easy to obtain sufficient fresh and unaltered material out of the rock. The analysis gave the following results :—

	I	II.	
SiO_2,	76·961	64·66	
Al_2O_3,	5 101	20·03	Very little iron.
Fe_2O_3,	2·344		
CaO,	7·064	1·21	
MgO,	0·295	—	
K_2O,	4·262	8·61	
Na_2O,	1·818	5·44	
Loss by ignition,	2·102	—	
Phosphoric acid,	Trace.	—	
	99·943	99·95	

When we consider the mineral constitution of the rock as obtained by the microscopical analysis, we may admit that only 38 per-cent. of free silica (quartz and tridymite) and 62 per-cent. of sanidine were the proportion of the mixture of those constituents. We find in the rock 76·052 of silica, agreeing with Mr. Hardman's analysis. But the same proportion of mixture requires 12·4 per cent. alumina, 5·34 per-cent. potash, and 3·37 soda, all numbers much higher than those obtained by Mr. Hardman. The presence of epidote makes the presence of a greater amount of lime intelligible, but requires an equally higher per centage of alumina. The great loss by ignition supports the supposition, that the rock analyzed by Mr. Hardman, was not fresh and unaltered. The increase of lime, and the decrease in alumina, potash, and soda must be put to the account of the decomposition.

The high per-centage of silica in Mr. Hardman's analysis is only explicable by the presence of tridymite in the paste; the quartz enclosed in the rock alone is not sufficient to yield it.

* J. Roth—Beiträge zur Petrographie der plutonischen Gesteine. Berlin, 1878; p. xxxiii.

The sanidine is a very typical one, and as it is quite free from interstices of a triclinic felspar, it is a very decisive argument that the orthoclases also really embrace two modifications; often appearing in isomorphous mixtures; a kali or potash orthoclase, and a natron or soda orthoclase. The proportion of mixture in the sanidine of Tardree Mountain is potash : soda=1 : 1.

It seems, therefore, to be fairly proved, that the name chosen by me for the Rock of Tardree Mountain—"Tridymite-Quartz-trachyte," is justly according to its petrological characters.

II.

Olivinegabbro of Carlingford Mountain.

Another remarkable rock, of which I am indebted for specimens to Professor Hull, is that forming the ridge of the Carlingford Mountains, rising in the south of the Carlingford Lough, Co. Down.

Mr. Hull in his recently published excellent work—"The Physical Geology and Geography of Ireland," gives (pages 143-45) a description of the geological occurrence of this rock. He says :— "The whole of this group of hills is formed of felspathic and pyroxenic rocks of several forms and varieties graduating into one another, which the officers of the geological survey are fully persuaded are the representatives in time of those of the Mourne Mountains on the opposite side of the Carlingford Lough. Thus we may classify the two sets as under:

Pyroxenic Group (the more ancient) consisting of micaceous dolerite of Slieve Gullion, diorite of Trumpet Hill, dolerite and anorthite hypersthene rock of Barnavene and Slieve Foy.

Felspathic Group (the more recent) consisting of varieties of felstone, porphyry and syenite of the Carlingford Mountains, and representing the granite of Mourne."

It is the "anorthite-hypersthene" Rock of Barnavene, that caps the syenite rock in the rugged ridge of the above named mountain, of which I will give some petrological details, the results of my studies on thin slices of that rock.

The rock is largely crystalline granular, composed of a triclinic felspar, which Rev. S. Haughton has justly defined as an anorthite, with a dark green pyroxenic mineral, forming irregular crystalloids between the better developed felspars, of greenish greasy grains of altered olivine and metallic-like grains of magnetite.

Under the microscope the anorthite appears very clear and fresh, offering a very beautiful chromatic striation under crossed Nicols. The angle between the direction of maximum extinction and the line of limit of the twinned lamellæ was measured to 35.38° on both sides. It varies, but is not much greater or smaller than these numbers. Its optical behaviour accords perfectly with the chemical definition as anorthite. The felspar contains but two kinds of interspaces—empty cavities and fluid cavities, often in long lines one after another. The fluid cavities contain bubbles, and the very small bubbles are in a very rapid movement; the larger ones are immovable. By heating the preparation to 100° C, the fluid shows no expansion and therefore seems to be but a watery solution.

The pyroxenic mineral appears under the microscope to take all the decisive characters of diallage. Its crystalloids are sometimes very numerous, but of a very irregular aspect, as they are mostly squeezed between the anorthite prisms. The observed optical orientation in the different parts of such a crystalloid proves it to be but one individual. The colour is pale grey green, without a trace of dichroism. The optical character is that of pyroxene; the angle between the direction of maximum extinction of light, and the vertical axis of prisms is 39-40 degrees. That is a very decisive character as against *hypersthene*, that being an orthorhombic mineral, must offer a parallel orientation of the axes of elasticity and the crystallographic axis.

The interstices are also very characteristic, just as we know in other diallages. Very little black bands and needles, or long pipe-like cavities are accumulated following the lamellar cleavage of the diallage and form long dull stripes alternating with zones free of interstices. The brownish interstices of distinct forms which we know of in the diallage of Labrador are not entirely absent, but are not frequent. They seem to be negative forms of the diallage itself, filled with a secondary reddish matter. Fluid cavities, with very moveable bubbles and also glassy interstices with fixed cavities are very numerous. In some places the diallage alters into a green dichroitic matter, which I am disposed to take for smaragdite, that amphibolic mineral being associated with the pyroxene in some Gabbros and the Eklogites.

The olivine appears clearly only in the thin slices, because it

is always covered by magnetite and therefore is not visible at the surface of the rock-specimens. It becomes entirely colourless in the sections, its borders are of a green yellow colour, a complete net-work of magnetite is spread through it and makes it partly non-pellucid. It contains glassy interstices, and many very little opaque needles, all disposed in a parallel direction. But that direction is parallel to the line of maximum extinction of light, and that is very distinctive as against diallage, where the direction of maximum extinction is oblique to the position of the interstices. The olivine appears partly altered to a green fibrous matter, polarizing like serpentine. After this description of the mineral constituents of the rock of Carlingford Mountains there cannot be any doubt of its classification. It is not an hypersthene rock, because it does not contain the orthorhombic pyroxene: it is not a syenite because it contains neither amphibol nor orthoclase, but it is a very typical Gabbro of the group characterised by the presence of olivine, and is not very different from the rocks described by Mr. Pettersen* from Store Bekkafjord, in Norway. From a cursory examination it seems probable to me also that one or another of the dolerites from Killala Bay, Co. Mayo, may be placed in the same group of rocks.

* N. Jahrb. f. Min, 1876, p. 174,

IV.—ON THE MINERALOGY OF THE COUNTIES OF DUBLIN AND WICKLOW.

BY

The Rev. SAMUEL HAUGHTON, M.D., Dublin: D.C.L., Oxon.;
Professor of Geology in the University of Dublin.

[Read March 18, 1878.]

The most convenient method of describing the minerals that occur in these counties, is to state in succession the minerals that are found in each of the several rock formations, referred to by the Rev. Maxwell Close, in his sketch of the Geology of the neighbourhood of Dublin.

1. THE MINERALS OF THE DUBLIN AND WICKLOW GRANITES. These minerals are twofold.

(A) *The Constituent Minerals.*

(B) *The Accidental Minerals.*

(A) *The Constituent Minerals.* The granites of Dublin and Wicklow are quinary, consisting of the following minerals :—

1. Quartz.
2. Orthoclase Feldspar.
3. Albite Feldspar.
4. Margarodite Mica.
5. Lepidomelane Mica.

1. The Constituent *Quartz* is grey, watery, transparent, and has a mean specific gravity = 2·645.

2. The Constituent *Orthoclase Feldspar* is milk white, opaque; and has a mean specific gravity = 2·540.

Its mean chemical composition, taken from seven specimens, of which three were from Dublin localities, and four from Wicklow localities, is as follows :—

Orthoclase (mean of seven Specimens.)

Silica,	64·59	per cent.
Alumina,	18·31	"
Lime,	0·25	"
Magnesia,	0·58	"
Potash,	12·23	"
Soda,	2·75	"
Loss by ignition,	0·58	"
	99·29	

3. The Constituent *Albite Feldspar* has, hitherto, been found in separate crystals, in one locality only (Dalkey); but it enters largely into the composition of the granite rocks.

Its chemical composition is as follows:—

Albite (Dalkey Quarry.)

Silica,	64·70	per cent.
Alumina,	21·80	,,
Potash,	2·84	,,
Soda,	9·78	,,
Fluorspar*	0·80	,,
	99·92	

4. The Constituent *White Mica* (Margarodite) of the granites, often occurs in flat rhombic prisms, or in hexagonal plates, formed from the former by the replacement of the acute angles; the angles of the lozenges are 120° and 60°; and the crystals are Biaxial, the plane of the optic axes tracing the major diameter of the lozenge.

The following measurements of the angle between the optic axes have been recorded:—

1. Three Rock Mountain,	53°	8′
2. Glendalough,	70	4
3. Mount Leinster,	72	18
4. Lough Dan,	70	0
5. Glenmalure,	67	11
6. Poulmounty,	76	15

The average chemical composition of the white mica is as follows:—

Margarodite (Mean of four specimens.)

Silica,	44·58	per cent.
Alumina,	32·13	,,
Iron peroxide,	4·57	,,
Lime,	0·78	,,
Magnesia,	0·76	,,
Potash,	10·67	,,
Soda,	0·95	,,
Loss by ignition,	5·34	,,
	99·78	

The amount of water of crystallisation present in this mineral

* The Albite was found in small crystals lining cavities in the granite, and encrusting crystals of Orthoclase; and it was associated with similar small crystals of accidental purple fluorspar, from which it was separated with difficulty.

separates it completely from *Muscovite*, of which it is considered by Dana to be an altered variety.

5. The Constituent *Black Mica* (Lepidomelane) of the granites occurs in hexagonal plates, and is Uniaxial. Near Ballyellin, (Co. Carlow) it is found associated with Margarodite in large plates; these plates are formed in about equal parts, of Lepidomelane and Margarodite, which fit into each other at angles of 120°—This fitting is purely mechanical and due to the fact that the angles of the Margarodite lozenges are 60° and 120.° Lepidomelane is essentially an iron-potash mica, and is distinct from Biotite, which is an iron magnesia mica. It is completely decomposed by hydrochloric acid. It has the following chemical composition:—

Black Mica (Lepidomelane.)

Silica, . . .	35·55	per cent.
Alumina, . . .	17·08	,,
Iron peroxide, . . .	23·70	,,
Lime, . . .	0·61	,,
Magnesia, . . .	3·07	,,
Potash, . . .	9·45	,,
Soda, . . .	0·35	,,
Iron protoxide, . . .	3·55	,,
Manganese protoxide, .	1·95	,,
Loss by ignition, . .	4·30	,,
	99·61	

The granite axis of Leinster runs from Rockabill to Poulmounty, N.N.E. to S.S.W., a distance of 90 miles.

Eleven specimens taken at about equal intervals along this axis gave the following mean chemical composition:—

Average Leinster Granite.

Silica, . . .	72·07	per cent.
Alumina, . . .	14·81	,,
Iron peroxide, . . .	2·25	,,
Lime, . . .	1·63	,,
Magnesia, . . .	0·33	,,
Potash, . . .	5·11	,,
Soda, . . .	2·79	,,
Loss by Ignition, . . .	1·09	,,
	100·08	

From this table, combined with the preceding tables, we obtain

the following simultaneous equations, to determine the per-centages of the constituent minerals in the average granite :—

Let	Q	= the per-centage of		Quartz.
	O	„	„	Orthoclase.
	A	„	„	Albite.
	W	„	„	White Mica.
	B	„	„	Black Mica.

(1) Silica, . . .	7207 =	100 Q +	64·95 O +	64·70 A +	44·58 W +	35·55 B.
(2) Alumina, . .	1481 =	—	18·31 O +	21·80 A +	32·13 W +	17·08 B.
(3) Iron peroxide, . .	225 =	—	—	—	4·57 W +	23·7 B.
(4) Lime, . . .	163 =	—	0·25 O	—	0·78 W +	0·61 B.
(5) Magnesia, . .	33 =	—	0·58 O	—	0·76 W +	3·07 B.
(6) Potash, . . .	511 =	—	12·23 O +	2·84 A +	10·67 W +	9·45 B.
(7) Soda, . . .	279 =	—	2·75 O +	9·87 A +	0·95 W +	0·35 B.
(8) Loss by ignition, .	109 =	—	—	—	5·84 W +	4·30 B.

If we select the four equations containing the largest per-centages, viz—The alumina, potash, soda, and iron peroxide equations, we find after several reductions—

$$A = 18{\cdot}0 + 0{\cdot}156\ W + 0{\cdot}191\ B.$$
$$O = 37{\cdot}65 - 0{\cdot}909\ W - 0{\cdot}819\ B.$$

These equations show the manner in which the two feldspars are related to the two micas.

We find finally—

$$B = 5{\cdot}81 \text{ per cent.}$$
$$W = 19{\cdot}16 \quad „$$
$$O = 15{\cdot}44 \quad „$$
$$A = 22{\cdot}10 \quad „$$

Inserting these values into the last seven equations, we obtain—

—	Observed.	Calculated.	Diff.
Alumina, ...	1481	1476·06	+4·94
Iron peroxide, . . .	225	224·99	+0·01
Lime, ...	163	22·28	+140·72
Magnesia, ...	33	41·27	−8·27
Potash, ...	511	511·45	−0·45
Soda, ...	279	280·64	−1·64
Loss by ignition, . .	109	126·89	−17·89

The agreement between calculation and observation is as close as could be expected; and the errors in the magnesia and loss by ignition, are, doubtless, errors of observation, due to the small magnitudes to be ascertained. The excess in the lime is real, and must be accounted for by the existence of a small quantity of paste, in the form of a silicate of lime.

The quantity of silica required to saturate 140·72 parts of lime is about 351·8; from which we infer that the paste amounts to 4·92 per-cent. of the rock.

The mean composition of the Leinster Granite is, therefore, as follows:—

Quartz,	32·57	per cent.
Orthoclase,	15·44	"
Albite,	22·10	"
Margarodite,	19·16	"
Lepidomelane	5·81	"
Paste (silicate of lime)	4·92	"
	100·00	

(B) *The accidental Minerals* found occasionally in the Dublin and Wicklow Granites are:—

Beryl,	Pale, greenish, opaque crystals. Loc. Dalkey, Killiney, Glenmalure, Glenmacanas.
Spodumene,	Long, bent, greenish grey prisms. Loc. Killiney.
*Killinite** (altered *Spodumene*).	Fibrolamellar, light green to brownish yellow, brittle; sp. gr. 2·56. Loc. Killiney.
Schorl,	Black. Loc. Clarinda Park, Kingstown; Dalkey, Three Rock Mountain, Stillorgan, Roundwood, Glenmalure, Poulmounty.
Garnet,	Small red and brilliant crystals. Loc. Dalkey, Killiney. Cinnamon colour. Loc. Glenmalure, Kilranelagh.
Fluorspar,	Small cubes. Loc. Golden Bridge. Octohedra, lining cavities. Loc. Dalkey Island, Dalkey Quarry.
Apatite,	Light green, translucent, hexagonal prisms, with lateral edges replaced. Loc. Three Rock Mountain, Killiney Hill.
Agalmatolite,	Loc. Dundrum, Luganure.

2. The Minerals of the Metamorphic Slates of Dublin and Wicklow.†

In addition to the Micas and Hornblende forming constituent

* The so-called *Killinite* is an altered *spodumene*, from which the lithia has been washed out by weathering.

† The absence of Garnet, Idocrase, and other lime minerals from the metamorphic slates of Leinster is remarkable and very different from what is observed in Donegal and elsewhere.

elements of the Metamorphic Slates, the following minerals are occasionally found:—

Andalusite, . .	Loc. Lugduff, Douce, Luganure, Glendalough, Glenmalure.
Chiastolite (variety of *Andalusite*),	Loc. Killiney, Aghavanagh, Baltinglass Hill.
Staurotide, . .	Loc. Killiney, Glenmalure.
Hornblende, . .	Radiated. Loc. Killiskey, Crystallized, dark green. Loc. Kilranelagh.
Jasper-agate, . .	Loc. Lainbay Island.
Mocha Stone, .	Loc. In pebbles found on the sea-beach, Co. Wicklow.
Zircon, . . .	Loc. Croghan Kinshela.
Gold, . . .	Loc. Croghan Kinshela.
Magnetite, . .	Loc. Croghan Kinshela.
Chlorite, . .	Loc. Glenmacanas; Howth.
Spinel, . . .	Small rolled grains. Loc. Croghan Kinshela.
Platinum, . .	Loc. Croghan Kinshela.
Wood-tin, . .	Loc. Croghan Kinshela.

3. THE MINERALS OF THE CARBONIFEROUS LIMESTONE OF THE CO. DUBLIN.

The Minerals found, occasionally, in the Calp limestone and Lower limestone of the Co. Dublin are few in number. Among them may be mentioned:—

Lydian Stone, .	Calp limestone (*passim*).
Iron Pyrites, .	Well formed crystals, occurring in sheets, lining joints in the Calp limestone.
Asphaltum, . .	Solid, opaque, resinous black lustre, conchoidal fracture. Loc. Castleknock.
Anthraconite, .	Loc. Castleknock.

4. MINERALS FOUND IN THE MINES OF THE COUNTY WICKLOW AND COUNTY DUBLIN.

Iron Pyrites, .	Loc. Sulphur mines, Vale of Avoca.
Fluorspar, . .	Large yellow and pale violet blue cubes. Loc. Glendalough mine.
Schieferspar, .	Loc. Luganure mines.
Barytes, . .	Loc. Killiney Hill; Luganure mine; Glenmalure mine; Clontarf.
Native Silver, .	Loc. Ballycorus mine.
Horn Silver, . .	Loc. Ballycorus mine.

Brown Hæmatite, .	Loc. Glenasplinkeen.
Manganese Oxides,	Loc. Glenasplinkeen; Howth.
Native Copper, .	Loc. Cronebawn; Ballymurtagh.
Copper Pyrites, .	Loc. Cronebawn; Ballymurtagh; Avoca.
Tinstone, . .	Loc. Croghan Kinshela, in small rolled fragments and detached worn crystals.
Carbonate of Lead,	Loc. Luganure mines.
Sulphate of Lead, .	Loc. Luganure; Ballyoorus.
Phosphate of Lead,	Loc. Glenmalure.
Galena, . .	Loc. Ballycorus; Luganure; Glendalough.
Blende, . .	Loc. Clontarf; Glenmalure.

V.—SOME REMARKS ON INTER-GLACIAL EPOCHS, IN REFERENCE TO FAUNA AND FLORA EXISTING AT THE PRESENT DAY IN THE NORTHERN HEMISPHERE, BETWEEN THE PARALLELS OF 81° AND 83° N.,

BY

H. W. FEILDEN, F.G.S.

[Read May 20, 1878.]

In the brief paper that I have the honour of submitting to your notice, it is my desire to draw your attention to the theory of intercalation of series of warmer climates during what is called the Glacial Epoch.

In accordance with the opinions of Professor Oswald Heer and the late Sir Charles Lyell, the existence of Inter-Glacial Periods has been indisputably evidenced by the Dürnten beds of Switzerland, and the Forest bed of our Norfolk coast; and while Professor Heer considers that the Dürnten lignite beds represent the existence of a climate similar to that now existing in Switzerland, Lyell remarks that the Forest bed of Cromer presents a singular analogy to that of Dürnten, and that "both of them alike demonstrate that there were oscillations of temperature in the course of that long period of cold."*

Mr. James Geikie in his valuable work, "The Great Ice Age," has likewise adopted the theory of the intercalation of warmer climates to account for the inter-glacial beds of Scotland. In fact, so many of our greatest modern authorities have given their adhesion to this theory, that it may almost be regarded as an accepted fact amongst modern geologists. That the so-called inter-glacial beds of Scotland and England were deposited between the commencement of the Glacial Epoch and its final withdrawal from Great Britain, is a well-established fact; but the question I am desirous of presenting to your consideration is, whether the so-called inter-glacial beds represent what Lyell terms "oscillations of temperature," or merely modifications of temperature due to

* Lyell. Principles of Geology, vol. i. p. 196. Eleventh edition.

alteration in the levels of land-masses, and the consequent change in their character as condensers of moisture, with probably a change also in the direction of the oceanic currents.

My suggestion, that it may not be necessary to connect the so-called inter-glacial beds with sudden changes or oscillations of temperature, is based upon the results of observations in Grinnell Land during 1875-76.

Having been fortunate enough to pass twelve months in the most northern portion of the earth that civilised man has yet visited, a region subjected to as rigorous extremes of cold as any yet recorded, where the sun remains below the horizon at mid-day for five months, where the mean annual temperature is—3°·473, where a minimum of—73°·75 was registered during the month of March, and where for only three months of the year the mean temperature rises up to and above the freezing point of fresh water, viz. +32°·455 in June; +38°·356 in July; +31°·913 in August. I was impressed with the fact that this region is undergoing less glaciation than Greenland, lying twenty degrees of latitude to the southward in the parallel of Shetland, and differing remarkably from the northern part of Greenland, lying between the same parallels, and separated by a narrow water-way not twenty miles across.

In Grinnell Land, from lat. 81°·40′ N. to lat. 83°·6′ N., no glaciers descend to the sea, no ice-cap buries the land; valleys from which the snow is in a great measure thawed during July and part of August stretch inland for many miles, and the peaked mountains snow-clad during the greater portion of the year, in July and August have great portions of their flanks which rise to an altitude of 2,000 feet bared of snow.

The opposite coast of Greenland presents a very different aspect a *mer-de-glace* stretches over nearly its entire surface, its fiords are the outlets by which its great glaciers protrude into the sea. In Petermann Fiord the ice cap with its blue jagged edge lying flush with the face of the lofty cliffs was estimated to be forty feet thick.

When we turn to the Flora and Fauna of Grinnell Land the difference is equally astonishing; some fifty or sixty flowering plants are found in its valleys, and between latitudes 82° and 83° N., I have seen tracts of land so profusely decked with the blos-

soms of Saxifraga oppositifolia that the purple glow of our heath-clad moors was brought to my recollection.

Musk oxen in considerable numbers frequent its shores; the Arctic fox, the wolf, and ermine, with thousands of lemmings live and die there. The bones of these mammals, along with those of the ringed seal (*Phoca hispida*), are now being deposited in considerable quantities in the fluvio-marine beds now forming in the bays and at the outlets of all the streams, or rather summer torrents of Grinnell Land. With these bones will be associated those of birds, such as geese and sea-gulls. Numerous mollusca and crustacea, many species of rhizopods, with the remains of land and sea plants, will there find a resting place.

Supposing that these beds were examined at some future period under conditions, when the glacial epoch had disappeared from the surrounding area, it would be difficult to realise that they were contemporaneous with the beds formed under the Greenland ice cap in the same parallel of latitude and on the opposite shore of a channel not twenty miles across.

In the one case, enormous thicknesses of till with ice-scratched stones have in all probability been deposited; in the other, fluvio-marine beds containing a comparatively rich assemblage of marine and land forms, with river-rolled pebbles, would be brought to light.

In the face of these facts is it incredible to suppose that the inter-glacial periods of Great Britain are due not so much to "oscillations of temperature" as to alterations in the amount of moisture in the atmosphere, and the position of the land-mass regarded as a condenser.

It is evident that the glaciation of Greenland and the west shore of Baffin's Bay and Ellesmere Land is not a result altogether of degrees of heat and cold, or in other words, temperature, but equally the result of geographical position which causes these regions to act as mighty condensers, throwing down in the form of snow the heated vapour of the south, and so effectually eliminating the moisture from the air that a tract of country like Grinnell Land lying still further to the north and subjected to an equally rigorous climate, is comparatively exempt from glaciation.

VI.—THE PHYSICAL GEOLOGY OF THE NEIGHBOURHOOD OF DUBLIN.

BY

REV. MAXWELL H. CLOSE, F.G.S.,

With a Map.

[Read February 18th, 1878.]

THE following account of the Physical Geology of the country around Dublin has been drawn up, principally from the Maps and accompanying explanations (Nos. 102, 112, and 121) published by the Irish Geological Survey, from papers in the Journal of the Royal Geological Society of Ireland, in the Transactions and Proceedings of the Royal Irish Academy, and from the Journal of the Geological Society of London. For further information on the subject the reader may have recourse to the memoirs above named, to the late Professor Jukes' "Manual of Geology," to Professor Hull's "Physical Geology and Geography of Ireland," and to Mr. G. H. Kinahan's "Manual of the Geology of Ireland."

The immediate vicinity of Dublin is low-lying ground and was formerly called *Sean Magh Ealta Edair*, *i.e.*, The ancient plain of the flocks of Edar. It is part of the Carboniferous Limestone plain which so largely occupies the central region of Ireland, and which only reaches the coast in a few places, as near Dublin. On the south side of Dublin the older rocks emerge from beneath the Limestone and rise to form the hill country of S. Dublin, Wicklow, and Wexford counties. Northward of Dublin Bay there are isolated exposures of the older rocks in the Hill of Howth, the islands of Ireland's Eye and Lambay, on the adjoining coast at Portrane, and in the country around Balbriggan.

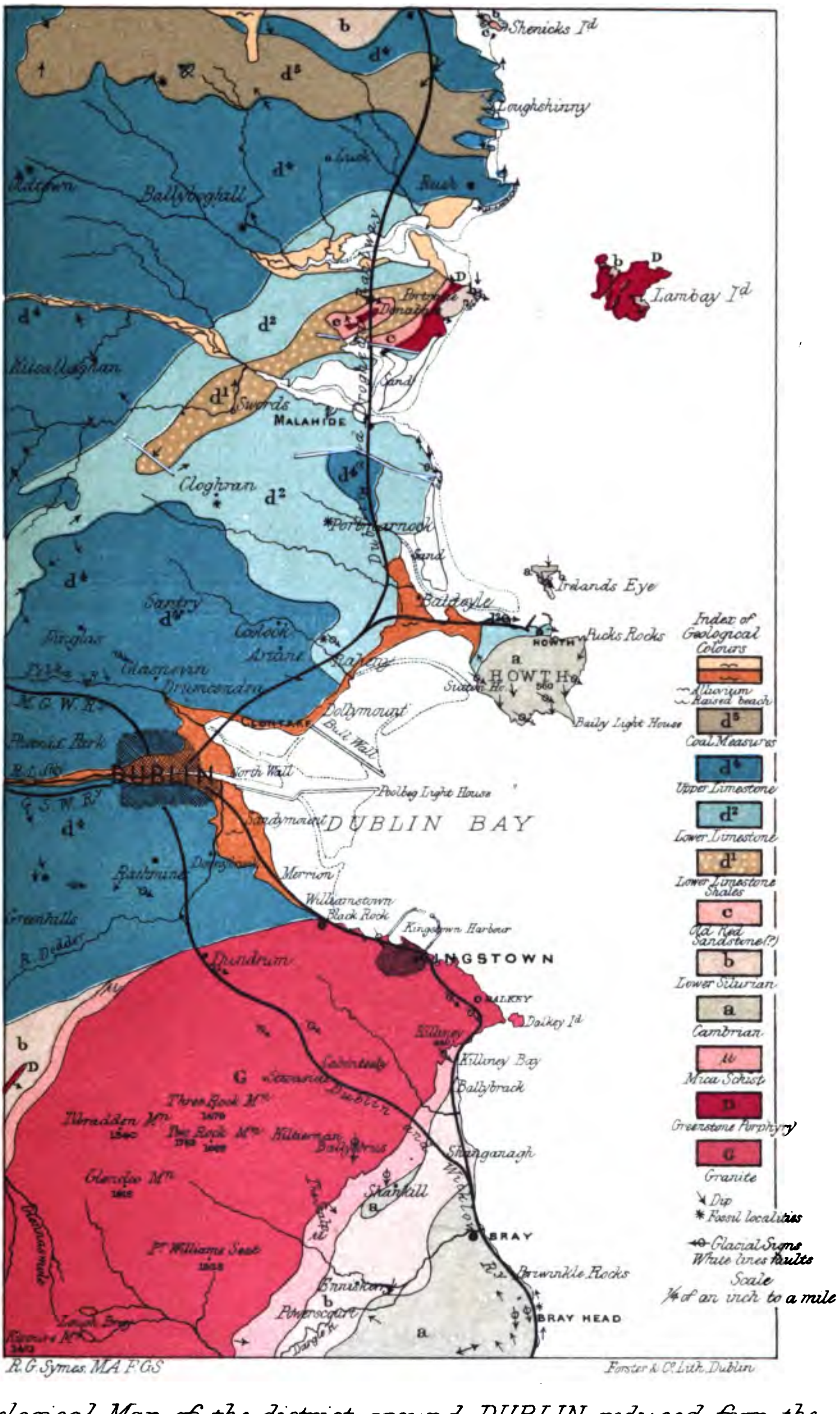
The following are the formations which present themselves within the district now to be described, viz., Cambrian, Lower, Silurian, Old Red Sandstone (?), Carboniferous Limestone, Upper Carboniferous Shales (Yoredale), Granite and other igneous rocks, and Pleistocene Drifts.

The accompanying map, drawn by Mr. R. G. Symes, F.G.S., of the Irish Geological Survey shows the boundaries of the surface exposures of the various formations; it is therefore unnecessary to describe them here. We shall adhere, as far as possible, to the chronological arrangement of our subject.

CAMBRIAN (correlative with the Longmynd rocks; "Lower Cambrian" of Sedgwick). Rocks of this formation constitute the whole of the Hill of Howth whose highest point is 563 feet (the low-lying north-western part of the peninsula is covered with Carboniferous Limestone). They occupy also the northern and western parts of Ireland's Eye, the island on the north side of the Howth Peninsula. In the southern part of our district there is a small exposure of them forming the upper part of Carrickgollogan Hill, or Shankill, 912 feet, between the Scalp and the sea. They then emerge on the near side of the town of Bray and extend thence along the coast for about 14 miles. They then leave the coast but still extend southward as far as the latitude of the town of Wicklow, that is for a length of sixteen miles altogether, with a mean width of about five miles, and they appear again in the S.E. part of county Wexford. In addition to Shankill, already mentioned, the principal eminences into which they rise near the southern part of our district are Bray Head, 793 feet, the Little Sugar Loaf, 1,120 feet, the Great Sugar Loaf, 1,659 feet, and the Downs Hill, 1,232 feet. This broken ridge, or line of hills, was called by Sir Roderick Murchison, the backbone of Ireland. As neither the bottom nor the top of the formation is visible, its thickness in this district cannot be ascertained.

Hill of Howth.—The Cambrian Rocks which form the hill part of the peninsula of Howth are generally greenish-grey, sometimes green and red, grits and slates, with numerous bands of quartz-rock, often of considerable thickness. A fine section of the rocks is displayed in the sea cliffs along the eastward and southern sides of the peninsula, for a length of at least three-and-a-half miles. The beds are much contorted and faulted; but it would appear that they have, in the mass, an E. and W. strike, with a general steep dip to the S.

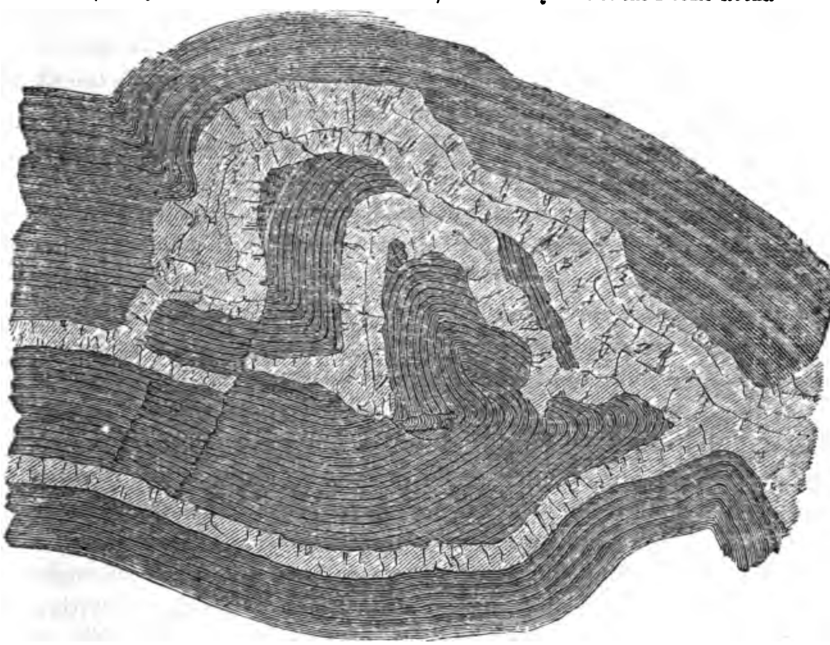
Many of the quartzose rocks on the S. side, as also those of the N.E. angle of the peninsula, have a peculiar nodular structure. A great number of trap dykes are to be seen in the cliff



Geological Map of the district around DUBLIN reduced from the maps of the Geological Survey of IRELAND.

sections all the way from Casana Rock, on the E., to a little beyond Drumleck Point on the S.; most of these are only to be reached in a boat. Some of them, as for instance that at the Bailey lighthouse, are composed of basalt. Notwithstanding certain lithological peculiarities in some of the rocks of Howth Hill, there can be no doubt but that they belong to the same formation as those of Bray Head, &c., viz., the Cambrian, since *Oldhamia antiqua* (not very well preserved) was found in them by Dr. J. Kinahan, at Puck's Rocks, near the N.E. point of the peninsula.

PLAN.—Quartz-rock and Slate near Howth, immediately east of the Needle Rocks.



Drawn to scale (8 yards to an inch) by the late Mr. John Kelly.

Bray Head.—The precipitous sea-side of Bray Head presents for a length of nearly two miles, a fine continuous section of the Cambrian Rocks, which here are greenish, reddish, and purplish, grits and slates, with bands of quartz-rock. The beds have a general dip to N.N.W., or N., at from 40° to 70°. Allowing for contortions and faults there must be a thickness of nearly one mile of the formation exposed here. Several thick bands of

quartz-rock strike across the Head. They give rise to the ridges and knobs on the top of the hill. Some of them are cut off by a fault which runs parallel to the shore line, and thus do not appear in the sea-cliff section. One, which is seen on the shore between Periwinkle Rocks and Brandy Hole, and is 50 yards thick, passes across the summit 653 feet and then, by a curious accident, is met at the fault by another very similar one which extends for three quarters of a mile farther to near Kilruddery House. Another prominent band of quartz-rock appears on the shore at half-a-mile N. of the point of Bray Head. It is pierced by one of the railway tunnels. It (that is its visible part) is clear of the fault just mentioned and runs across the summit, 793 feet, the highest point of Bray Head, and thence extends, as it would seem, continuously by Windgate to near Belmont House, altogether a distance of two miles. These bands of quartz-rock are generally conformable with the stratification of the other rocks; but it is interesting and important to observe that they sometimes assert their independence of the stratification in a way that is not easy to explain. Mr. G. H. Kinahan, in his "Manual of the Geology of Ireland," contends that this is only to be explained by such quartz-rock (which he distinguishes from quartzite) being intrusive.

A faulted dyke of greenstone is seen in the coast section, just on the S. side of the railway tunnel above mentioned. This is an interesting object, as, with the exception of the dyke on the shore at Greystones, 2½ miles farther S., no other igneous dykes have been found in the Cambrian rocks of that neighbourhood, although they are so numerous at the Hill of Howth.

The *Little* and the *Great Sugarloaf* are composed of rocks which are lithologically similar to those of Bray Head, but with a greater proportion of quartz-rock, of which their summits are formed. They appear to be contained in a synclinal basin, through the middle of which the intervening valley of Kilmacanogue has been denuded. No fossils have been detected thereabouts except at the E. side of the Little Sugarloaf, and the W. side of the other.

Greystones, which is situated on the coast, a little beyond the southern margin of our map, has a good exposure of the Cambrian rocks on the shore. These dip, for the most part, steeply northward, and contain two massive beds of quartz-rock and the in-

trusive dyke, already mentioned, of coarse crystalline diorite, a rare feature in that neighbourhood.

Disturbance and Denudation.—Owing to the confused condition of the strata the relation between the Cambrians and the immediately superincumbent rocks is very obscure; so much so that in this neighbourhood it could not be determined; but in the country south of the Devil's Glen, Co. Wicklow, in the hills near Ashford, it is seen that the Cambrians had suffered considerable disturbance and denudation before the overlying strata were laid down unconformably upon them. The actual junction of the two formations can be seen in Pollshone Harbour, north of Cahore Point, and in Bannow Bay, both on the coast of Wexford. The overlying rocks are Lower Silurian, of Llandeilo and of Caradoc age. It seems most probable that the disturbance and denudation were contemporaneous with the similar actions which produced the unconformability which is now known to exist between the Tremadoc and the Arenig rocks.

LOWER SILURIAN (below of Llandeilo, above of Bala or Caradoc, age, "Upper Cambrian" of Sedgwick).—The rocks of this formation here consist of thin-bedded, black, and grey, sometimes greenish, rarely purple, clay slates and fine greenish, and dark grey, grits, with, very rarely, beds of limestone (while purple slates, rare in this formation, are common in the Cambrian, black slates, common in this formation, have not been found in the other). The thickness of the strata in this district is unknown, but it must be many thousand feet; in S. Wexford it must be 10,000 or 12,000 feet.

Around *Balbriggan*, beyond the northern boundary of the map, there is an exposure of this formation, about 40 square miles in area, the southern extremity of which just comes within the limits of the map. Shenick's Island, the largest of the Skerries, is composed of beds of this formation dipping S.S.E., at 40° to 50°, on which lies, at one place, a small thin flake of nearly horizontal beds of conglomerate and sandstone, belonging, if not to the Old Red Sandstone, yet to the base of the Carboniferous formation. The Lower Silurian grits and slates are interstratified with beds of contemporaneous trap, often porphyritic, with layers of trappean ash. Some of the trappean rocks are several hundred feet in thickness. This interesting spot should be visited at low tide.

At *Portrane* there is, on the shore, a small, but very noticeable, exposure of this formation. The beds are sometimes much contorted, but their general dip on the shore is towards S. of E. The rocks consist of slates and shales containing graptolites and trilobites, with some grits and, more especially, highly fossiliferous beds of limestone; all the fossils being of Bala or Caradoc age. There are also several interstratified beds of trappean ash, evidently connected with the contemporaneous felstone porphyry close by on the W. and S. There is, in some places, a well defined cleavage whose planes dip about S. 30° E. at 40°.

Lambay Island is 2½ miles off Portrane. It is principally composed of felstone porphyry with various small masses of Lower Silurian stratified rock, some probably caught up in the felstone. The slates of some of these yield graptolites. At Kiln Point, on the shore near the S.E. angle of the Island, there is a mass of thin beds of limestone which contain Bala fossils; they have thin earthy shales between them. The felstone has sent veins and strings into the lowest bed of the limestone; but it has not had much altering effect thereon. The geological interest of this island is increased by the occurrence, near its N.W. point, of a remnant sheet of Old Red Sandstone (?) not more than 50 feet thick. This consists of sandstones above, and a conglomerate below. It extends along the S. side of Broad Bay for a length of nearly one furlong; the beds dipping N. at from 60° to 30°. The base of the conglomerate is well seen; it lies unconformably on the Lower Silurian ash and slates, which, at this place dip S. at about 50°, and must be now inverted. The N. part of this remnant sheet is cut off by an E. and W. fault.

The black slates which occupy the low south-eastern part of *Ireland's Eye*, and which apparently rest unconformably on the Cambrian rocks, most probably belong to this formation.

At a few miles southward of Dublin, the Lower Silurian sets in as the surface formation; it extends thence to Waterford Harbour, except that it is interrupted by the Cambrian and granitic exposures.

The rocks of this Lower Silurian area within the district with which we are now concerned, are unfossiliferous; but in Wicklow, at Slieveroe, near Rathdrum, and in the Co. Wexford, they have yielded various fossils of Bala or Caradoc type. The small exposure of this formation at the Chair of Kildare, twenty-four miles

W. by S. from Dublin, has afforded fossils of the same type. The great probability is that much of the unfossiliferous portion of the formation is of the same age as the fossiliferous, though the lower part of it may be, as some of it certainly is, of Llandeilo age. The general strike of the beds, throughout the area now in question, is N.N.E. and S.S.W.; this obtains on both sides of the granite exposure, the longest axis of which has nearly the same direction. All along the sides of the granite, the rocks are changed into mica slate.

Besides the contemporaneous felstone of Portrane and that of Lambay, already mentioned, there are some sheets of felstone porphyry near Bohernabreena, which are most probably contemporaneous; being interbedded with the Lower Silurian strata. There are also masses of basalt and dolerite at Ballynascorney, which are probably intrusive; though rudely conforming to the strike of the slates, &c. These two places are at the mouth of the interesting valley of Glennasmole, three or four miles S. of Tallaght. We may here mention that, in Wicklow and Wexford, of the long ranges of igneous rocks, whose trend corresponds generally with the strike of the Lower Silurian strata, the felstones are usually contemporaneous, the others principally intrusive.

GRANITE.—As we are following chronological order, we must now turn our attention to the granite, before proceeding to the next sedimentary formation. The granitic exposure of this neighbourhood, which is the largest continuous one in the British Islands, extends from Kingstown, on the north, to near New Ross, in Wexford, on the south, a distance of nearly seventy miles. It has a width of from seven to seventeen miles. It must extend northward from Kingstown, beneath the sea, into Dublin Bay, and probably farther still, as we find the small island Rockabill, five miles off Skerries, and just outside the northern boundary of the map, to be composed of granite of the same type. But of course the Rockabill granite, though evidently belonging to the same mass, may not belong to the same surface exposure thereof; as is the case with the Carnsore granite at the S.E. point of the Co. Wexford. There are some small isolated granite protrusions in the Co. Wicklow, which differ importantly, as to composition, from that with which we are now concerned; these, however, are outside of our present subject.

The age of the granite of the main mass is determinable

within, what may be called, comparatively narrow limits. The facts that the granite has been intruded into the Lower Silurian rocks, and that the slates of that formation have been metamorphosed all along the border of the granite into mica schist, evidently by the action of the granite, show that the intrusion of the granite was later than the formation of those rocks. On the other hand, the facts that, in the Co. Kilkenny, the Old Red Sandstone reposes undisturbedly on the granite and has not been altered thereby, and that its beds sometimes contain a quantity of granitic pebbles and detritus, show that the protrusion of the granite took place before the deposition of those rocks.

The main granite exposure includes the principal mass, with the highest summits, of the S. Dublin, Wicklow, and Wexford hills; while the Silurian rocks form lower ground on each side, with some subordinate hills. This, in connexion with the fact that the general strike of the Lower Silurian rocks is very nearly parallel with the length of the granite exposure, on each side, might, at first sight, give rise to the idea that the granite, while being forced into the Silurian strata, had broken through them, upheaving them and throwing them off on either side, so as to make them dip away in both directions. But what evidence there is on the point bears against this supposition. The granite has nowhere brought up the underlying Cambrian rocks on its flanks; nor has it thus brought up the lower of the Silurian rocks. It is true that the metamorphosed Silurian slates, close along the sides of the granite, usually dip away therefrom, on each side; but notwithstanding this, the Silurian strata on the western side of the granite, though evidently much folded and contorted, seem nevertheless to dip, as a whole, towards the granite; so that the higher beds come against it; and it would appear that in the Co. Wexford, also, on the eastern side, they are the upper beds which border the granite (although it is not so, northward of that, in the Co. Wicklow.) Again there are patches of altered Silurian slates lying on some of the highest parts of the granite hills, including the very summit of Lugnaculliagh itself, 3,039 feet, the highest point of all. It is just at the highest part of the granite, where it has escaped denudation, that we find the schist still lying upon it; while on the other hand, it is just where the valley of the Slaney cuts across the range of the granite hills, and the denudation has been greatest,

that we find the width of the granite exposure to be greatest. All these facts point to the conclusion that the granite protrusion may not have broken through the thick mass of Silurian strata, and that it was brought to the surface by the subsequent denudation, which has wrought parts of it into low ground as about Kingstown, Carlow, St. Mullins, &c.

The granite, as already observed, has metamorphosed the Lower Silurian slates, all along the line of its contact with them, into regular mica schist; the alteration extends from the surface of the granite through a thickness of several hundred feet and dies away gradually. The grit bands in the slates are, as might have been expected, but little changed. The width of the metamorphosed rock, as measured on the surface of the ground, is greater on the east, than on the west side of the granite; which seems to indicate that the bounding surface of the granite descends less steeply beneath the slates on its east, than on its west, side. There seems to be some connection between this fact and that already alluded to, viz., that the small outbursts of granite are on the east and that there are none in the Silurian on the west side of the main granite exposure.

The contact of the granite with the Silurian rocks is strikingly exhibited on the shore of Killiney Bay, at the base of Killiney Hill. It is there seen that the granite has irregularly penetrated the Silurian slates and sent off veins into them; it has also caught up what are clearly separated masses of the slate rock, converting all into mica schist and developing therein stellate crystals of chiastolite. Not far off, on the south side of Rochestown Hill, N. and N.W. of Killiney Park, the granite has forced several narrow tongues into the slates, nearly along the direction of the bedding (see the plan of this in the Geological Survey "Explanations," 112, p. 35).

The Rathmichael relief tank of the Dublin waterworks, on the northern hip of Shankill, was excavated directly on the boundary line of the two formations. The boundary was distinct; but not so much so as at Killiney; and there was a peculiar lumpy, lenticular-nodular structure common to the rocks on each side of the boundary; the greatest extension of the flake lumps being parallel to the surface of separation. At the southward end of the Scalp—a remarkable physical feature to be men-

tioned again—the mica slate can be seen in close proximity to the granite; crystals of chiastolite are to be found in it there also. The contact is seen in some places on the west side also of the granite, but only imperfectly, and not under specially interesting circumstances.

It has been suggested that some of the granite of the main mass may have been produced by extreme metamorphism from the rocks in which it is contained; but the similarity of its composition in different places, as far as is known, seems to throw a very great difficulty in the way of this hypothesis. No doubt, as the granite has acted upon the Silurian rocks with which it has come in contact, these rocks must, in some way or other, have reacted upon the still tractable materials of the unsolidified granite. Probably it is to such reaction that the interesting phenomenon to be seen on the S. slope of Rochestown Hill (a locality already mentioned) is due. In a quarry there, just N. of the garden wall of Killiney Park, it may be observed that the crystals of black mica in the granite are arranged in layers parallel to the bounding surface between the granite and the slates. This is visible for a distance of ten or twelve feet from the boundary, which is very abrupt and definite.

The chemical and mineral composition of this granite has been elaborately investigated by the Rev. Dr. Haughton, F.R.S. For the full results of his analyses and the discussion thereon, the reader is referred to Dr. Haughton's Paper in the *Quart. Journ. Geol. Soc.*, London, vol. xii., 1856; and to the joint Paper, by Professor Jukes and himself, in the *Trans. Royal Irish Academy*, vol. xxiii., 1858.

The analyses show comparatively slight differences in the proportions of the constituents of the rock in different localities. The following table gives the mean chemical composition of specimens obtained from eleven generally widely separated places:—

Silica,	72·07
Alumina,	14·81
Peroxide of Iron,	2·22
Lime,	1·63
Magnesia,	0·33
Potash,	5·11
Soda,	2·79
Loss by ignition,	1·09
	100·05

The mineral constituents are (1) Quartz, (2) Orthoclase felspar in distinct crystals, (3) Albite felspar (in paste), (4) White mica (Margarodite), (5) Black mica (Lepidomelane). The quartz, orthoclase, and white mica, are always present in distinct grains; the black mica is not always, but frequently, present along with the white, and in smaller proportion. The orthoclase crystals are sometimes large, making the rock porphyritic. The felspar paste contains much more soda than the orthoclase crystals. This suggested the idea to Sir Robert Kane, Dr. Haughton, and others, that the paste might be partly composed of some other felspar besides orthoclase. None such, however, had been seen in this granite, until Dr. W. H. Stacpoole Westropp detected what seemed to him to be some small crystals of albite in some granite from the neighbourhood of Kingstown. These proved to be really albite on being analysed by Dr. Haughton. Since then, Professor Hull has, by means of the microscope, observed in the paste of this granite, besides orthoclase, a triclinic felspar, which is doubtless albite. (In the Mourne granite the albite, as well as the orthoclase, can be distinguished in every hand specimen.) The white mica of the Leinster granite sometimes becomes *plumose*. At different places about Killiney and at Foxrock, near Carrickmines, it has been found collected into nests, with a beautiful flowing, feathery arrangement. It is believed that this is a speciality of this neighbourhood.

For the accidental minerals occurring in this granite and developed in the Silurian rocks metamorphosed thereby, see the Article on the mineralogy of this district.

The jointing of the granite can be well studied in many places, as about the Killiney Hills, especially in the large, now disused, quarries on Dalkey Hill. Several joint systems of different degrees of importance can sometimes be seen intersecting at the same place. The joint surfaces are almost always very even and smooth, entirely different, as to character, from surfaces of fracture; so that however the joints may be connected with the contraction of the granite in cooling, they are something more than mere planes of splitting. The main joints have generally a marked parallelism, sometimes for considerable distances.

It is principally the primary joints, and rarely the others, that have the slickenside coatings so often to be seen on those surfaces.

It is, of course, quite possible that there may be friction slickensides on planes of dislocation in the granite. There must have been such planes produced during the disturbances after the Carboniferous age, when the granite had been thoroughly solidified, and great friction must have taken place along them; but the slickensides so frequently to be seen in the granite joints of this neighbourhood are, at least as a general rule, most clearly structural and not the result of friction. The slickenside striations of the quartz coating of a joint surface are often accompanied by capillary schorl, the needles or fibres of which are accurately parallel to the slickenside striation and unquestionably form part of the phenomenon. The great majority of the slickenside-bearing joints of a neighbourhood have a very observable nearness of direction with each other; the mean dip of these surfaces is at about 30°, so that the variation in the direction of the planes is only one half that of the strikes of the planes. Moreover, the striations are not only strictly parallel on the same surface, but they very seldom deviate much from the mean direction in their vicinity; showing that their directions have been influenced by some common cause. This can be well seen in many places; of which one of the most easily indicated and accessible is the shore at Sandycove (between Kingstown and Dalkey), from the bottom of Burdett Avenue for some distance eastwards.

The granite is often penetrated by dykes and veins of eurite (which may be called a fine close-grained granite with very little or no mica) and by veins of quartz. These, when they intersect can often be seen to be of different ages; and they are sometimes faulted. The eurite veins may be intrusions of later date than the solidification of the surrounding mass, or they may be only infiltrations into contraction fissures; the quartz veins have been doubtless formed by infiltration.

Occasionally, though apparently very rarely, the granite in this neighbourhood exhibits an obscure concretionary structure. Sometimes a freshly exposed joint surface will show indistinct concentric rings of colour two or three feet in diameter, usually iron staining, which might, at first sight, lead to the supposition that the joint had cut across a concretionary spheroid; but it will usually be manifest on closer inspection that the phenomenon is confined to the joint itself. In some places, as near Mur-

phystown, the outer part of a roundish projection of granite seems to be a slightly separated coat or shell of uniform thickness, which might be removed by wedges. This, also, might be supposed at first sight to be an instance of concentric structure; but it appears to be really in some way the effect of the atmosphere, although the granite is quite sound and undecomposed. (This is well seen on a much larger scale on one of the Mourne granite mountains.)

In some places, owing to the decomposition of the felspar, the granite has, for a depth of several feet, become so rotten that it can be chopped out with a spade; it is then used as "freestone" for sanding kitchen floors. This phenomenon may be sometimes observed at some height on a steep hillside, *e.g.*, above Ticknock, on the west side of the Three-Rock Mountain, as well as on low ground. It seems to be the effect of atmospheric action; a necessary condition being some local peculiarity in the felspar; but what this may be does not seem to have been ascertained.

Disturbance and Denudation.—There is a wide unconformability between the next succeeding formation and the Lower Silurian on which it rests; showing that there was great disturbance and denudation between the completion of the Lower Silurian strata and the commencement of the deposition of the others; this being the second of which we have evidence in this district. Mr. Jukes thought it probable that the Lower Silurians were already disturbed, to some extent, when the granite came up into them; the intrusion of the granite, if it did not directly cause, was, at least, accompanied by further disturbance of those rocks. At any rate, the great disturbance that actually took place would afford opportunity to the denuding agencies of working very unequally on different parts of the great stratified mass. Whilst in some areas of this district several thousand feet in thickness of the Lower Silurians still remain, in others the ground was bared of all such rocks before the Old Red Sandstone was laid down. This was, almost doubtless, the case where the Limestone lies directly on the Cambrian, as at Howth, and it was inevitably so where the Limestone stretches over the Silurian on to the granite, as it does a few miles S.E. of Dublin. But as the Cambrian floor of the Silurian sea was doubtless irregular in this district, and as the granite

came up irregularly into the Lower Silurian strata, we cannot form any idea what thickness of the latter may have covered those places when the denudation began; though it was probably something considerable. But there is good reason for believing that, near the town of Wexford, the whole thickness of the Lower Silurian formation of this region was stripped off the Cambrian rocks before the deposition of the Old Red Sandstone in that vicinity. The Silurian strata seem to have been there laid down evenly on the surface of the already contorted and denuded Cambrian mass; and it is just in that neighbourhood, alongside of the Cambrian boundary, that we have the clearest evidence of the great thickness of the Silurian rocks, viz., perhaps ten or twelve thousand feet. Some such thickness of Lower Silurian beds must have stretched over the now exposed Cambrians, near at hand, and by far the greater part must have been removed by the denudation of which we are now speaking, as is shown by the remains of the Old Red Sandstone which lie on the Cambrian rocks at a distance of only 1¼ mile from the nearest and lowest Silurian stratum. The re-exposing of the Cambrian rocks nearer Dublin must have been, likewise, chiefly performed by this denudation, though doubtless partly by that to be considered farther on.

The fact that the Old Red Sandstone conglomerates near the granite in Co. Kilkenny and in Co. Waterford contain pebbles of that rock is another proof of the great denudation that had taken place before the deposition of these conglomerates; since, as far as we know, true crystalline granite is formed only under the conditions of very slow cooling and great pressure, that is to say at a considerable depth beneath the surface.

OLD RED SANDSTONE (?)—This may be but the basal or shore beds of the Carboniferous formation. Although there are four, and possibly five, presentations of these rocks in this district, they are all very small. This is on account of the (conformable) overlapping which hereabouts runs through the whole series of Carboniferous strata. The post-Carboniferous larger-scale disturbances were, in this region, comparatively small (though not so in the S. of Ireland); and it was only here and there that the later denudation was able to bring these underlying beds to the surface. No fossils have been found in them.

The largest exposure of these rocks is at Portrane and Donabate, where an upheaval has enabled the subsequent denudation to lay them bare between the Silurian and the Carboniferous Limestone. The whole thickness of these beds in this place does not exceed 350 feet.

There is another outcrop of these strata near Lyons, 14 miles W.S.W. of Dublin, where they have been exposed by the removal of the Limestone, for a very small length and width. The remnant patches of these beds to be seen lying on the upturned edges of the Lower Silurian rocks on Shenick's Island (Skerries) and on Lambay Island have been already mentioned.

Along the base of the cliffs at Balscaddan Bay, on the E. side of Howth Harbour, there is a coarse, brecciated conglomerate of quartz-rock materials, red and yellow stained, which, from its proximity to the Lower Carboniferous Limestone, doubtless belongs to these underlying beds.

Just outside the railway at Blackrock Station there is the still exposed part of a rock, the rest of which has been covered by the railway embankment. It consists of a remarkable firmly compacted pure granite breccia. The granite from which it was formed and the remains of the limestone which must have covered it are both visible close by in the People's Park. But as the latter is Upper Limestone, this breccia cannot belong to, nor lie beneath, the base of the Carboniferous formation which could be overlapped only by Lower Limestone.

Carboniferous Limestone.—This formation is one of the salient features of the geology of Ireland. It extends continuously from the E. to the W. coast of our island, occupying the greater part of the central plain and its ramifications. Its greatest thickness is from 2,500 to 3,000 feet. From want of suitable continuous sections its thickness near Dublin cannot be determined, although the bottom of the formation occurs at Donabate, and the top of it only three miles northward of that, a little beyond Rush.

Lower Limestone Shale.—This consists of dark shales and thin flaggy limestones. It surrounds the exposure of Old Red Sandstone or of basal Carboniferous conglomerate at Donabate and runs thence towards the S.W., along the crest of an anticlinal fold, the whole length of the narrow exposure being seven miles. It contains a small characteristic assemblage of fossils. Its whole thickness does not exceed 200 feet.

Carboniferous Limestone Proper.—This has been separated into three divisions, Lower, Middle, and Upper. The distinction between these, however, is principally lithological and local in character; it cannot be generally carried out. The Middle division seems to be the least constant, and about Dublin the Middle and Upper are not distinguishable. In this district the Lower Limestone is generally a pale grey crystalline limestone, sometimes regularly bedded, sometimes in amorphous masses. The neighbourhood of Dublin, for a radius of several miles, is on the Middle and Upper Limestone which here consist generally of dark, earthy limestone, called calp, interstratified with dark grey shales, and with frequent layers or irregular nodules of chert. This is quarried for building stone and road metal. Occasionally beds of good pale limestone, fit for burning occur therein; these sometimes abound in fossils.

The lower division of the Limestone lies directly on the Cambrian rocks at Howth, and its upper division, which has overlapped its own inferior parts, extends on to the Silurian rocks near Skerries, and on to the Silurian rocks and granite at four miles southward of Dublin.

In the last mentioned vicinity the following remarkable circumstance is to be observed. Over all the district between the Liffey and the foot of the Dublin hills the prevailing dip of the Limestone strata (neglecting slight contortions) seems to be everywhere southwards, or towards the emerging Silurians and the granite. This may be partly explained either by undulations of the beds whose opposite dips happen to be concealed, or by a series of faults running nearly E. and W., which repeat the beds; otherwise it would be necessary to attribute to the black, earthy limestone a thickness greater than the known thickness of the group anywhere else. A similar peculiarity of dip may be observed near the northern extremity of the map. The Upper Limestone beds on the shore S. of Skerries and also two miles inland dip northwards towards the Lower Silurian rocks on which they rest.

The actual contact of the Limestone and Cambrian is visible on the W. shore of the Howth peninsula about 200 yards N. of Bottle Quay. The contact of the Limestone and granite is nowhere exposed; the two are visible about a stone's-throw from each other on the shore at Blackrock in the People's Park. In a Limestone

quarry-pit near Carlow, whence stone was being taken to build a new church, some years ago, the workmen, to their great inconvenience, came down upon the granite.

Sometimes masses of the Limestone rock have been more or less highly dolomitized, so that the bedding sometimes becomes obliterated. Examples occur in Howth harbour, and one mile W. thereof close by the railway, and one mile S. of this latter place, also near Milltown bridge and on the shore S.E. of Malahide, and near Loughshinny. Anthracite, probably of animal origin, or perhaps derived from marine algæ, has been found in the Limestone at Castleknock; and sometimes bed faces are covered with a thin film of black carbonaceous matter.

The Limestone, occasionally, contains large and small fragments of granite, both rounded and angular, sometimes associated with granite sand, as also slabs of mica schist, as near Crumlin and at Milltown. These extraneous masses are sometimes quite isolated in the limestone matrix; as though they had been carried out from the land into comparatively deep water in the Carboniferous sea by some unusual means of transport, as, for instance, by being floated by plants to whose roots they may have been attached. Fragments of (unmetamorphosed) Silurian material are found in some of the Limestone beds at Kilsallaghan and Lispopple, eight miles W. by S. of Portrane. In the ravine of the Delvin river, near the Naul, and on the shore, both near Rush, and near Baldungan, two and a half miles northward thereof, there are beds of conglomerate of which the blocks, pebbles, and fragments, both rounded and angular, and layers of sand are of Silurian origin; these were evidently shore beds.

It seems most probable that the Calp, or dark earthy limestone so prevalent around Dublin, was largely formed of fine mud derived from the black Lower Silurian slates. The small proportion of lime in the Calp may account for the fact that there are, apparently, no underground streams in this vicinity. The percolating water, not being able to dissolve the Calp, could not make subterranean passages, as it has done to such an extent in the Limestone of the W. and S. of Ireland. There is a strong spring of fresh water rising through the sea water in Howth Harbour. This comes doubtless from a subterraneous passage in the Lower Limestone of that locality, which is pure, excepting the very local dolomitization near the spot.

It is very remarkable that the above-mentioned conglomerates near Rush and near Baldungan contain pebbles of Carboniferous limestone. In other places the limestone is thickly interspersed with small, angular fragments of older beds of the same formation; these are very visible when they are of a different shade of colour from the matrix. These facts seem to imply that there were minor, pretty even, upheavals and subsidences during the deposition of the Carboniferous Limestone. and that older beds were uplifted from the sea, and had acquired considerable hardness when later beds were being formed partly from their angular and rolled debris. The phenomenon of lenticular bedding, often to be observed in the Limestone, indicates that there were irregular changes of condition connected with the deposition of the strata.

Upper Shales.—A remnant strip of this formation extends from Baldungan towards the Naul, as indicated near the northern extremity of the map. Its length is nearly ten miles, its mean width about one and a half. The rocks consist of hard, splintery shales, interstratified, in some places, with thin grits and flagstones. They used to be called Coal Measures, that term being applied, in a wide sense, to include, not only the Coal Measures proper, but all the strata between them and the top of the Carboniferous Limestone. They are to be correlated with the Yoredale beds. Only the lower part of the group remains, the thickness being about 500 feet. The overlap above mentioned, still continues into this formation, as can be seen near the Bog of the Ring, where these Upper Shales evidently extend beyond the Limestone, so as to come directly upon the Lower Silurian. Though this formation is properly described as conformable with the Limestone, yet, occasionally, local unconformabilities have been noticed between the contiguous beds of the two series. This is what might have been expected, as the great general subsidence during the Carboniferous age must have been, not only interrupted, but temporarily reversed at the end of the Limestone period. As already mentioned, a similar temporary reversal seems to have taken place during the deposition of the Limestone itself; this being apparently necessary to explain the presence of fragments of earlier beds in the later beds of that formation.

The Upper Shales in this district contain a very characteristic assemblage of fossils. There is a very interesting coast section

across the end of this Upper Shale area, for which see Geological Survey Explanations 102, page 62.

The beds of this formation are in a synclinal basin, as is invariably the case in Ireland, and the low hills which they form are hills of circumdenudation. This brings us to the

Disturbance and Denudation which took place after the completion of the whole of the Carboniferous formation, this being the third of which we have evidence in this district. Although in the western and west-central parts of the Carboniferous Limestone plain of Ireland the beds of that formation extend evenly and almost horizontally over considerable areas, yet elsewhere they have undergone disturbance and contortion. Such has been the case in the district with which we are now more immediately concerned, although by no means to the same extent as in the South of Ireland. In many places the beds have steep local dips. They are interestingly contorted at Loughshinny, three miles S. of Skerries, evidently by horizontal compression, which has produced even reversed faults. They are also strongly contorted in a quarry beside the bridge at Lucan and elsewhere. This disturbance being greater in the S. and S.E. of Ireland, has there produced a general system of cleavage pervading all the rocks from the lowest to the highest. The strike of this cleavage is in the S. about W.S.W. and E.N.E.; in the S.E. it gradually turns to about S.S.W. and N.N.E., and it seems to die away a little outside the southern boundary of the map. This disturbance seems to have been (at least principally) effected at a time earlier than the Permian age; so that if, as seems most probable, no formations later than the Carboniferous were laid down in this district until the Drift period, the denuding agencies had nearly all the long period from that time to the present in which to work their will on the disturbed rocks. However this may be, they have very effectually availed themselves of the opportunities afforded them.

When we consider that the Upper Shales just mentioned, and the overlying beds as far as they remain to us, are seen over the greater part of Ireland, to lie in synclinal basins, and that they are always remnant patches, whose limits are due to denudation and not to the dying-out of the beds, we reasonably conclude that these supra-Limestone beds once extended over a great part of the area now called Ireland, and that they have since been removed by denudation. The country around Dublin

must have had over 2,000 feet of such strata removed in this way, besides some of the underlying Carboniferous Limestone, though generally not very much of this has been eroded, as in this vicinity we are on the Middle and Upper Limestone. Doubtless, at Portrane the denudation has removed the whole thickness of the Carboniferous formation, together with the few hundred feet of the thinning out Old Red Sandstone, if it be such, which once covered the Silurian at that place—probably a thickness of over 4,000 feet altogether.

It is on such considerations that Professor Hull has founded his explanation of the origin of the Scalp, a remarkable gap, three miles W. by N. from Bray, which cuts across a spur ridge from the mass of the Three Rock mountain. The water falls both ways from the Scalp. Professor Hull's suggestion is that that gap was cut by a river which began to flow when the Upper Carboniferous strata still covered the neighbourhood, including the site of the ridge, and which became unable to continue passing through that part of its valley when the general denudation had worn down the softer rocks of the upper part of its course more deeply than it was able to erode its bed through the hard granite and mica slate of the ridge, which was already existing, though doubtless not in its present condition.

Notwithstanding the deposition of Drift which has taken place over so much of this district, and the great accumulation of it in certain places, very little of the denudation of which we have been speaking can have been effected during the Drift period to supply the materials then spread about, since the traces of the general glaciation wrought immediately before the Drift period still remain visible in so many places.

GENERAL GLACIATION.—The signs of the action of the general ice-sheet which once covered Ireland are abundant in the vicinity of Dublin. They consist (1) of rock rounding, smoothing, and striation, and (2) of Boulder Clay, or Lower Boulder Clay, as we may call it, without committing ourselves to the hypothesis that is sometimes implied in that title.

The rock-grinding can be seen in many places on the quartz-rock of Howth, Ireland's Eye, Shankill, and Bray Head, on the Old Red Sandstone conglomerate near Donabate station, on the felstone there beside the railway, on that of Lambay Island, on the granite (generally recently stripped of its drift covering) near Dundrum,

about Foxrock, and Dalkey, on the Killiney Hills, &c. It is often strikingly displayed on limestone freshly bared for quarrying; though, of course, almost immediately removed. There was a very fine example of this in a quarry near Finglas Bridge (the one in which the beds are nearly horizontal). The abrading agent has frequently produced very observable crag-rounding, as distinct from mere surface-rounding, though generally accompanied thereby, as on Ireland's Eye, Shankill, and Bray Head. This phenomenon should be viewed from a sufficient distance—say from half a mile to a mile and a half—and in the afternoon, when the sun is favourably situated for showing the effect, owing to the direction of the glaciation. The highest point at which the striations can be certainly found is on the very summit of Shankill, near the Scalp, 912 feet. Unfortunately the granite hills would not preserve the striations except under special circumstances, otherwise those marks of ice-action would be traceable to much greater heights.

The Lower Boulder Clay is of the usual well-known character. It is generally a very stiff clay containing well rubbed, blunted, and scratched, though sometimes angular, and very rarely rolled, stones and blocks; these are often two feet in length, though they are usually much smaller. Except in the S.E. part of this district the great majority of the stones are limestone, even in places situated some miles from the edge of the limestone ground. As the great ice movement was from the extensive limestone plain, we should naturally expect a preponderance of limestone blocks in the boulder clay; but it is sometimes very surprising that the boulder clay, after having been swept along over two or three miles of granite ground, should have picked up so few granite blocks as it has done. In such cases the largest blocks in the clay belong to the local rock. The upper surfaces of such blocks are sometimes ground, smoothed, and scored in the same manner as the surface of the living rock, and in the same direction.

In the N. and N.W. neighbourhood of Dublin the boulder clay has been left in more or less well-defined ridges, which are quite distinct from the eskers to be mentioned presently, and which we shall call drumlins; these are not only parallel with each other but also with the rock-striation of their immediate

vicinity. It is perfectly certain that it must have been the rock-scoring agent which produced the boulder-clay ridges. Having ascertained this, we can often recognise the course of the flows of the universal ice-sheet by the mere inspection of an accurately shaded map. See the shaded Ordnance inch maps, Nos. 100, 101, 110, and 111. These drumlins are even more strikingly displayed in other parts of Ireland.

The rock-scorings and these ridges show that the great glacial flow from the north-westward was divided not far from Maynooth, evidently by the obstruction of the Dublin and Wicklow Hills; see the glacial map of Ireland in Prof. Hull's Physical Geology and Geography of Ireland, p. 210. Agassiz, when in Dublin in 1840, having seen but little of the glacial phenomena of the neighbourhood, naturally supposed that those hills must have been a centre of glacial dispersion. But it is very interesting and remarkable to find that they were not so, but that they were invaded *ab extra* by a great ice-flow which can be traced backward to the less important hills of Fermanagh. They had, however, afterwards, their own small local glaciers as we shall see presently.

STRATIFIED DRIFT.—Immediately over the Lower Boulder clay, which was clearly the *moraine du fond* of the great ice-flow from the north-westward, comes a deposit of stratified water-arranged and washed gravels and sands. These, which we shall call the Middle Sands and Gravels, extend from the present sea level up to a considerable elevation on the hills. They reach 1,100 feet on the S.E. side of the Three Rock Mountain, 1,300 feet on the W. side of that hill, on the summit of the *col* connecting it with Kilmashogue Mountain, 1,250 feet at 2¼ miles W. by S. of the last, and the same elevation at one mile W. of this last on the eastern side of Mount Pelier. The distance between the first and the last mentioned spots is five miles.

These elevated parts of the gravels and sands are as well washed and sorted as those on the low grounds; they moreover consist as largely of foreign materials; although resting at those heights on granite hills they are part of the "limestone gravel." Pieces of flinty chalk and other far-transported stones and fragments of marine shells can be found in them as in the low-lying gravels. The shells found in the gravels of this neighbour-

hood all belong to species now inhabiting the neighbouring seas; they are usually much broken, especially those found at the higher elevations. The highest places at which they have been found are at Ballyedmonduff, 1,000 feet, and at one furlong southward of Caldbeck Castle, on the above mentioned *col* between the Three Rock and Kilmashogue Mountains, 1,250 feet above the sea.

It is most probable that a large proportion of these deposits consists of water-rolled and rearranged materials derived from the Boulder Clay which seems to have suffered denudation and to have been removed in some of those places, at least, where the water-formed gravels lie directly on the rock. The gravels have been piled very irregularly; some valleys contain deep accumulations of it. Some places are bare of it, though situated at lower levels than others not far off which are deeply covered.

There are great collections of this formation in Killakee valley, in Glennasmole (shells), in many places in the valley of the Dargle river from Bray towards Powerscourt Deer Park, in Glencullen, about Enniskerry, &c. There are fine natural sections in many places, especially Killiney Bay (shells) and Balscaddan Bay on the E. side of Howth Harbour (shells), and many good artificial sections in large gravel pits about the neighbourhood.

It is just possible that these gravels may have formerly reached higher elevations than those mentioned and have been washed down again. On the Two Rock Mountain, which might be called the southern and higher part of the Three Rock ditto, stones of two to four inches in diameter, and blocks of extraneous material can be found near the summit at 1,750 feet. There are two blocks of granite on the N.W. side of the Great Sugar Loaf, at the height of 1,480 feet, and several others at 1,300 feet; these are three miles from the nearest granite rock; there are some also on the upper part of Bray Head, five miles from the nearest granite. These may have been transported by floating ice, which agent has, doubtless, dropped the large blocks of (local) granite which may be seen resting on the surface of the above-mentioned elevated gravels of extraneous materials resting on the granite hills. The numerous fragments of chalk-flint and the pieces of Mourne granite that are found in the gravels may have been carried hither by floating ice; they may, however, have been gradually drifted along the coast by the ordinary action of the waves.

Upper Boulder Clay.—Over the generally well-washed and stratified Middle sands and gravels may sometimes be seen a nearly, occasionally quite, unstratified deposit, which we may call the Upper Boulder Clay, without implying thereby that it has been formed in the same way as the Lower Boulder Clay. It is of a looser, more earthy material, and may contain far-travelled stones. But as the nature of this deposit, if it be really a separate one, is obscure, and there is considerable difference of opinion thereanent, and as entering into controversy is outside our present business, we shall pass on to the next.

Eskers.—These seem to be the latest of these drift accumulations. We shall not now go into the difficult and vexed question of their mode of formation. They must be as old as the time of floating ice, as they sometimes have very large transported blocks lying *upon* them, just as the level drift often has. It is sometimes evident that these have not been brought out by denudation, but that they have been dropped on the esker by some agency that did not interfere with the gravel and sand already there; and the only agency that can be suggested is floating ice. The eskers consist of thoroughly well washed and generally stratified materials. Shell fragments have been found in them, but only in one or two instances. As their name implies, they are generally in the form of *ridges*, though they are often but more or less well-defined irregular mounds. There is a good specimen of a ridge esker at Greenhills, a couple of miles W. of Rathfarnham. Its whole length is nearly three miles, and its height from thirty-five to sixty feet. A road runs along the crest of its southern portion, where it is narrower and well-defined, for a length of two and a quarter miles. There is also a ridge esker at a place thence called Esker, on the S. side of the Liffey, six miles W. of Dublin, and there are irregular esker mounds in Stillorgan Park and elsewhere.

Local Glaciation.—This is doubtless the proper place in which to mention the glacial moraines which are to be found among the hills in the neighbourhood of Dublin. It is most probable that those moraines were finally left by the ice, as we now see them, about the time of the formation of the eskers or shortly after that.

Each of the two Loughs Bray (12 miles S. by W. from Dublin) occupies its own division of a laterally double hollow on the N.E. side of Kippure Mountain (granite, 2,473 feet above the sea). The

larger or Lower Lough Bray (elevation 1,225 feet) is dammed in by a glacial moraine, the two arms of which meet at the bottom of the lake and then descend towards the bottom of Glencree valley, near the head of which the lakes are situated. Their lower parts below the lake are covered with numerous large granite blocks, some of which must weigh about 200 tons. That part of the grounds of Lough Bray Cottage which is on the N. side of the lake is on a bank leaning against the hill side; the upper side of this bank falls to the hill side. The lower eastern *end* of the bank is beneath the water of the lake. This is clearly a latero-terminal moraine formed by the glacier when it had shrunk so as to be unable to fill the original moraine bed it had made for itself. (The jointing of the highest part of the precipice is well seen from the ground between the two lakes. In the lower part of the precipice the primary jointing dips inwards, and is as regular as stratification; at the summit it is horizontal.) The small Upper Lough (elevation 1,453 feet) might be considered by some the more interesting, glacially, of the two. It is contained in its own recess which is much less deep than that of the Lower Lake. If we may so express it, the width of the Upper Lake is greater than its length. Its longest axis is parallel to the cliff under which it lies and to the moraine dam. This dam is a well defined bank running all along the lower edge of the lake; at its middle part it rises about 90 feet above the water. It is represented, but without the following small details, on the shaded Ordnance inch map, 121. All along its top runs a small, very distinct, ridge or crest, which looks almost like an artificial bank, and close outside of this, for the S.E. half of its length runs a second parallel but not so regular crest. Several huge blocks of granite are scattered about on this moraine dam; one lies right on the first mentioned crest. Some of these must be 200 tons in weight; the largest (on the outer side of the moraine) measures 28 feet in width at its base, 26 feet in height, with a mean thickness of about 9 feet; it must weigh at least 250 tons. These blocks have, no doubt, come from the cliff on the opposite side of the lake. It is interesting to have this evidence of so great power in so small a glacier. No rock-scoring is to be seen; the rocks being all concealed by the moraine masses, except in the precipices over the lakes.

The hollow enclosing the Powerscourt deer-park seems to have contained a glacier. A little before reaching the Waterfall a bank is passed which might well be the terminal moraine of such glacier. This hollow, however, is at a low level.

Mullaghcleevaun (*i.e.*, Cradle mountain,) so called from the *cradle*, or hollow, containing its small lake is seven miles S.E. of Blesington and eighteen miles W.S.W. from Dublin; it rises 2,783 feet above the sea; the elevation of the lake being 2,244 feet. The damming-in moraine is sufficiently striking to be indicated in the shaded Ordnance inch map, 120.

These corries, or small cirques, like the rest among the Wicklow hills (except the North and the South Prison on Lugnaculliagh) face north-eastward; a usual circumstance with such glacier sites; the reason of which is obvious on consideration.

Pleistocene Mammals.—As the limestone forms plain ground in the neighbourhood of Dublin, with hardly any crag escarpments except in a few stream ravines, there is but little opportunity for the occurrence of caves sufficient to make retreats for the cave animals and to become receptacles of the bones of themselves and their prey. None such, therefore, have been discovered. Bones of bear have, however, been found in Co. Kildare, beside the River Boyne, at about two and a half miles above the bridge of the Midland Railway, 31 miles W. by N. from Dublin. They were embedded in peat or sand four feet below the surface. The skull is now in the Museum of the Royal Irish Academy; the rest of the bones were not preserved, although they were but little decomposed. Dr. Leith Adams considers that the skull is that of a young female of *Ursus spelæus*. In the same place were found many bones of deer.

A remarkable collection of the remains of *Cervus megaceros* has been discovered at Ballybetagh bog, parish of Kiltiernan, eight miles S.S.E. from Dublin. In 1847, whilst a watercourse was being cut through the bog, the heads and antlers, with other bones, of about thirty individuals of this deer were found within a space of 100 by 4 yards in vegetable compost and sand under peat, as also one head of *Cervus tarandus* or reindeer with the horns large and perfect. In 1875 Mr. Richard J. Moss, on further exploration, discovered the remains of about fifty other individuals; and since then Mr. William Williams, naturalist, has

obtained those of twenty-five more, with the horn of a second reindeer. Thus about 105 individuals of *Cervus megaceros* besides those, doubtless many, whose remains have not been exhumed, were buried at this Irish Big Bone Lick. The animals were nearly all males. Remains of this deer were found also in the great accumulation of gravel a little N. of Enniskerry; these, as might have been anticipated, were much decomposed.

Besides the remains of the two reindeer obtained at Ballybetagh, a very fine and perfect skull of this animal, with antlers, was found on the verge of Curragh bog, a couple of miles N.N.W. of Ashbourne, and 13 miles N.W. from Dublin. It is now in the National Museum of Ireland.

Raised Beach.—This can be seen in various places along the neighbouring coast. It is perceptible near Malahide, and on the W. side of Ireland's Eye. It forms the low narrow neck which makes a peninsula of the Hill of Howth. The flat ground extending along the coast from the mouth of the river Tolka to Merrion, and extending inland for some distance along each side of the Liffey and to Donnybrook, belongs to this formation. The remains of it can be seen at one spot, just S. of the mouth of the Shanganagh River, in Killiney Bay. It runs inland up the valley of the Bray river. It forms the Murrough on the near side of the town of Wicklow.

There is difference of opinion respecting this formation as occurring in this neighbourhood. Some authorities contending that the low raised beach of this neighbourhood corresponds with that which in S.W. Scotland is at the higher level of 25 feet. Others contending that, beside the lower beach of this neighbourhood, there are also traces of a 25-foot beach.

Submarine Peat.—Submarine peat occurs in many places around the east of Ireland. It often contains stumps of trees standing *in situ;* in some places turf is cut therefrom at low spring tides. It is said that peat has been brought up in Killiney Bay on the flukes of anchors. It occurs off the coast of Wicklow and Wexford, sometimes under four fathoms of water. If there be, as just now referred to, two raised beaches in this neighbourhood, this now-submerged peat grew subaerially of course, after the higher and probably before the lower beach was formed. This, if

correct, would indicate the following oscillations of level of the land. The land, having stood for some time while the upper beach was being formed, rose about sixty-five feet, when the now-submerged peat grew upon it; it then subsided a little more than sixty-five feet, and stood until the lower beach was formed; it then rose again, a few feet, to its present level.

RECENT PEAT.—Considerable portions of some of the hills are covered with what is doubtless to be called recent peat. On the summits of some of the hills, *e.g.*, Prince William's Seat, 1,825 feet, it is now being *removed* by atmospheric denudation, which seems to indicate that in such situations the conditions are not now as favourable as formerly for its growth and increase. At the head of Glencree, above the Reformatory, the turf lies on the granite to a depth of from six to twenty feet, and it is said that roots of lime and stems of fir, willow, &c., (the fir is unquestionable), are frequently met with in cutting it there; the elevation above the sea being 1,500 feet. This also seems to indicate some change in atmospheric conditions in such situations; as it is doubtful if trees could grow there now.

List of Places with Geological Phenomena of Special Interest.

Shenick's Island, Skerries. Lower Silurian, &c.

Lough Shinny and coast on each side. Limestone and Upper Shales, strong contortions, reversed fault, fossils.

Malahide shore. Lower Limestone Shale.

Portrane. Lower Silurian limestone, with fossils, &c.

Lambay Island. Lower Silurian limestone with fossils, felstone porphyry, remnant of Old Red Sandstone (?).

Howth Peninsula. Cambrian, numerous igneous dykes. Shell-bearing drift. Isthmus of Raised Beach.

Greenhills, beyond Crumlin. Esker.

Glennasmole. Felstone and basalt outside entrance. Deep shell-bearing Drift within.

Ballyedmonduff and Caldbeck Castle. Shell-bearing drift, 1,000 feet and 1,200 feet.

Blackrock. Nearest visible approach of Limestone to Granite, Granite breccia.

Dalkey. Extensive granite quarries on hill. Granite *roches moutonnées* near town.

Killiney Bay. Junction of Granite and Mica Schist. Shell-bearing drift.

Rochestown Hill. Junction of Granite and Mica Schist, laminated granite. Rock-scoring.

Kiltiernan. Cervus megaceros, C. tarandus.

Ballycorus. Disused mine, Smelting Works.

Scalp. Junction of Granite and Mica Schist. Physical feature.

Lough Bray. Physical feature, Granite jointing, glacial moraines.

Bray Head. Section in Cambrian, Oldhamia, &c. Glaciation.

Greystones. Section in Cambrian, Oldhamia, dyke, glaciation.

VII.—ON THE PALÆONTOLOGY OF COUNTY DUBLIN,

BY

WILLIAM HELLIER BAILY, F.G.S.

[Read February 18th, 1878.]

THE fossil-bearing rocks in the vicinity of Dublin, including the adjoining County of Wicklow, belong to the oldest series of formations, being of Cambrian, Silurian and Carboniferous age; with the exception of a few Pleistocene deposits, containing marine shells in gravels of the Glacial period.

The Cambrian fossils first claim our attention, as belonging to the oldest fossiliferous formation of the British Islands. From the Bray railway station, a walk along the shore of about a mile brings us to the commencement of the series of rocks forming Bray Head. Certain beds in the hard, sandy shales and slates may be seen to be covered with impressions and markings which were, evidently, organic; they have been described under the generic name of Oldhamia, after Dr. Oldham, who first made them known. Two species of these remarkable fossils were defined by Professor Forbes: viz., *O. antiqua* and *O. radiata.* He considered them to belong to the Hydrozoa, and to be allied to Sertularian Zoophytes. Others have considered them to be plants, if so, they are most probably Red Algæ, allied to the lime-secreting Corallines. They occur in both green and red or purple slates. On the shore, the best locality for *O. radiata*, is the "Periwinkle Rocks," at Bray Point, only to be reached at low water; the finely laminated green grits at this place being covered with their impressions, and about a mile and a-half further they are plentiful in certain purplish shaly beds, which are interstratified with thicker beds of grit, forming the cliffs rising from the sea at Bray Head, near the "Cable Rock." Good examples of *O. antiqua* may be obtained from red beds near the same place, but more inland, a little above the footpath, round the Head, and just within the boundary-wall of Kilruddery Demesne, also at other places close to the same footpath, in cuttings of the Dublin, Wicklow and Wexford railway, and in various places in the cliffs upon the shore.

Oldhamia antiqua has the appearance of a number of small fan-shaped tufts, arranged in an alternating manner, upon a zigzag axis. This species is also abundant and well preserved in the brown and purple slates of Carrick Mountain, County of Wicklow, accompanied there, as at Bray Head, by tracks and burrows of animals, which frequently occur in pairs, and resemble those from the Cambrian rocks of the Longmynd in Shropshire, named by Mr. Salter *Arenicolites didymus* and *A. sparsus*, species which are probably identical. The late Dr. Kinahan believed he had detected *Oldhamia antiqua*, accompanied by tracks, in brown laminated slates at "Puck's Rocks," near the "Nose of Howth." The specimen he collected, and presented to the Geological Survey Collection, is not, however, so distinct as those from Bray or Carrick Mountain.

Oldhamia radiata.—The most frequent form resembles a number of detached bunches of flattened sea-weed, without any connecting axis or stem, covering irregularly the thin laminæ of the rock, giving it a somewhat star-shaped appearance. This species is most abundant on the shore at Bray and Greystones Co. Wicklow.

Histioderma Hibernica is a fossil from the same rocks at Bray, described by Dr. Kinahan* as "the cast of a tentacled cephalobranchiate sea-worm, not very dissimilar from the common lug-worm (*Arenicola*) of our present seas." This fossil is of considerable size; it may be seen occurring as mounds on the surface of a large calcareous bed on the shore, a little south of the Periwinkle Rocks. These mound-like protuberances are about one inch and a-half in diameter, with a central depression from which proceeds a tubular opening of about half-an-inch in diameter, passing vertically through the rock from two to four inches, or even more, sometimes in a tortuous or curved manner. These fossils are entirely confined to Irish strata, excepting the double markings, supposed to be the burrows of sea-worms (annelidan), named by Mr. Salter *Arenicolites didymus* and *A. sparsus*. The *Oldhamia* and *Histioderma* have not been detected in the Cambrian rocks of the Longmynds, or those of North Wales.

Haughtonia pœcila, described by Dr. Kinahan, from red gritty beds, Periwinkle rocks, Bray Point, as an aggregation of the

* Journal of the Geological Society of Dublin, vol. viii., p. 71.

tubes of a gregarious Annelid, allied to Sabella (Jour. Geol. Soc. of Dublin, vol. viii. (1859), p.p. 116-118., figs. 1 and 2), appears to us to be scarcely definite enough to warrant its retention amongst the fossils of this formation.

Figures and more detailed descriptions of these fossils are given in the Journal of the Geological Society of Dublin (*loc. cit.*), the Transactions of the Royal Irish Academy, vol. xxiii. (1858); in the Geological Magazine, 1865, p. 385, &c.; and in the Explanation to sheets 121 and 130 of the maps of the Geological Survey of Ireland; a good series, including some of the figured specimens, being contained in the Geological Survey Collection, Royal College of Science, Dublin.

LIST OF CAMBRIAN FOSSILS.

Plantæ or Hydrozoa.

Oldhamia antiqua (*Forbes*), Bray Head, Carrick Mountain, County Wicklow; Howth, Co. Dublin.

„ radiata (*Forbes*), Bray Head, Greystones, Co. Wicklow.

Histioderma Hibernica (*Kinahan*), Bray Head, Carrick Mountain, Dublin.

Arenicolites didymus (*Salter*) } Probably identical, Bray Head,
„ sparsus (*Salter*) } Carrick Mountain.

LOWER PALÆOZOIC ROCKS, containing Caradoc-Bala species have been observed at several places near Rathdrum, in the County of Wicklow: more particularly at Rathdrum Hill, the Quarry near Rathdrum Bridge, and at Slieveroe. The following is a list of the fossils collected by the Geological Survey in this district:—*

[The prefixed asterisks are intended to represent the comparative abundance of the species.]

ACTINOZOA: *Corals.*

**Favosites fibrosus, branching and hemispherical varieties.

MOLLUSCA: *Brachiopoda.*

Discina perrugata?
Leptæna Griffithiana, new species (*Davidson*).
„ sericea.
Orthis calligramma.
„ elegantula.
Lingula brevis?

* Explanation to sheets 121 and 130 of the maps of the Geological Survey of Ireland, p. 16.

Conchifera.

Modiolopsis and Orthonota, species undetermined.

Nucleobranchiata (Heteropoda).

Bellerophon perturbatus.

ANNULOSA : *Echinodermata.*

Crinoid joints and stems.
Cystidean ? plate.
Glyptocrinus ; portion of column.
Palæasterina ? starfish.

Annelida.

Tentaculites Anglicus.

CRUSTACEA : *Phyllopoda.*

Beyrichia complicata.

Trilobita.

**Calymene brevicapitata.
Homalonotus bisulcatus ?
Lichas laxatus.
*Phacops Brongniarti.
Trinucleus concentricus.

North of Dublin, Lower Silurian fossiliferous rocks of Caradoc-Bala age again appear on the shore at Portrane, and at Lambay Island, County of Dublin; at both these places the lithological character of the rocks, black slates and dark grey limestone, with their contained fossils, are precisely identical. These black slates may be observed on the Portrane shore a little south of the first martello tower from the coastguard station, and on the east side of Lambay Island, north of Kiln Point. From them have been obtained one species of Graptolite, *Diplograpsus pristis*, having a central axis with a double series of cells arranged on either side.

The Silurian limestone is well exposed in prominent cliffs on the Portrane shore, at several places between the first and second martello towers, south of the coastguard station. These rough crags have all the appearance of an ancient coral reef; the chain coral, *Halysites catenularius*, *Heliolites*, *Favosites*, and *Cyathophyllum*, occur in profusion, being weathered out by sea and atmospheric action.

The following list of fossils from these places is derived from the memoirs of the Geological Survey of Ireland [Explanation to sheets 102 and 112., p. 11.]:—

LOWER SILURIAN: fossils; Portrane, and Lambay, County Dublin.

HYDROZOA: *Graptolites.*

Diplograpsus pristis.

ACTINOZOA: *Corals.*

Cyathophyllum; species not determined.
*Favosites cristatus.
" asper.
* " fibrosus.
***Halysites catenularius.
**Heliolites interstinctus, and variety megastoma.
*Syringophyllum organum.

MOLLUSCA; *Polyzoa.*

*Ptilodictya dichotoma.
* " acuta.

Brachiopoda.

Atrypa marginalis.
Discina; species undetermined.
Leptæna quinquecostata.
" sericea.
" tenuicincta.
Lingula; species undetermined.
Orthis biforata.
** " calligramma.
** " elegantula.
** " insularis.
" porcata.
** " testudinaria.
" vespertilio.
***Strophomena alternata.
* " rhomboidalis.
* " expansa?

Conchifera.

Ctenodonta; species undetermined.
Modiolopsis; do. do.

Gasteropoda.

*Cyclonema crebristria?
" rupestris?
Euomphalus, two species; one new, the other undetermined.
*Holopea concinna.
Murchisonia; two species undetermined.
Raphistoma; new species.

Nucleobranchiata.

Bellerophon subdecussatus.
„ new species, allied to acutus.

Cephalopoda.

Orthoceras remotum (*Salter mss.*)
„ species undetermined.
„ tenuicinctum ?

ANNELIDA.

Tentaculites Anglicus.

CRUSTACEA: *Trilobita.*

Agnostus trinodus.
Æglina mirabilis.
**Calymene obtusa.
*Cheirurus clavifrons.
„ bimucronatus.
**Cybele verrucosa.
***Illænus Bowmanii.
Lichas Hibernicus.
„ laxatus.
Remopleurides longicostatus.
*Sphærexochus mirus.
Stygina latifrons.
*Trinucleus seticornis.

Lower Silurian rocks, with accompanying fossils, are again exposed still further north of Dublin, on the coast north and south of Balbriggan. To the south, from half a-mile to a mile of Balbriggan, the rocks on shore at several places, black or dark grey slates, contain fossils, mostly Graptolites. The single-celled form, *Graptolithus Hisingeri*, occurs in profusion, with *G. tenuis* sparingly, and the double-celled and characteristic form of *Diplograpsus pristis* plentifully. Small orbicular Brachiopods, allied to *Crania*, are occasionally associated with the Graptolites.

About one mile and a-half north of Balbriggan, the rocks on shore near Lowther Lodge and west of the Cardy Rocks, consisting of grey and brown shales, are very fossiliferous; the small coral *Favosites fibrosus*, and Brachiopod shells *Leptæna sericea, Orthis calligramma* and *O. porcata, Strophomena alternata* and *S. deltoidea* being abundant, with the Trilobites *Cybele verrucosa Calymene brevicapitata*, and a small Phyllopod Crustacean, an undetermined species of *Beyrichia*. This assemblage of fossils indicates strata of Caradoc-Bala age.

Two other fossil localities, also in Silurian strata, have been observed more inland, one of them being a little south of Stamullin, close to the river Delvin, where a Crinoid head, doubtfully referred to *Glyptocrinus*, and single-celled Graptolites—probably *G. Hisingeri*—were long since obtained by the Geological Survey Collectors, from grey shales and grits. The other is situated about a mile and a-half west of Balbriggan, at an old quarry on the road to Balscaddan, where similar grey shales yielded a few fossils, amongst them *Orthis calligramma* and *Theca triangularis*. *

LOWER SILURIAN fossils; near Balbriggan, Co. Dublin.

HYDROZOA: *Graptolites.*

**Diplograpsus pristis.
***Graptolithus Hisingeri.
„ tenuis.

ACTINOZOA: *Corals.*

**Favosites fibrosus.

MOLLUSCA: *Brachiopoda.*

Crania?
**Leptæna sericea.
Orthis Actoniæ.
* „ calligramma.
* „ porcata.
*Strophomena alternata.
* „ deltoidea.

Pteropoda.

Theca triangularis.

ECHINODERMATA.

Crinoid fragments.
Glyptocrinus?

CRUSTACEA: *Phyllopoda.*

Beyrichia, species undetermined.

Trilobita.

Calymene brevicapitata.
Cybele verrucosa.

CARBONIFEROUS LIMESTONE is the prevailing formation in the immediate neighbourhood of Dublin, and although for the most part covered by drift, is observable at the numerous quarries opened for economical purposes, at coast sections, and Railway cuttings.

Sections of this formation are to be seen on the south of

* Explanation of Sheets 91 and 92, Geological Survey of Ireland, p. 21.

Dublin, between Milltown and Clonskea on the banks of the river Dodder, at several places near Rathgar and Rathfarnham, Kimmage, Crumlin, Goldenbridge, &c., Clondalkin and Lucan, all south of the river Liffey; and at Killester railway cutting and quarry, south of Finglas, quarries and cuttings at Blanchardstown, east and south of the village, on the north side of the river Liffey. All these are more or less fossiliferous localities, considered by the officers of the Geological Survey* to belong to the Upper Limestone ("Calp" of Sir Richard Griffiths), although the Palæontological evidence affords no grounds for such division. Quarries at Castleknock a little south of the village, and in the townland of Mitchelstown, three miles N.N.W. of Finglas, at Cloghran, Dunsink, north of Cappoge the large quarries at Saint Doulagh's, rocks on shore near Howth Lodge, and quarry to the south, near the Deer Park, are all in compact Lower Limestone, usually containing a large assemblage of fossils. At Balscaddan Bay, north of Howth Harbour, are Lower Limestone shales. These lower beds, consisting of dark earthy limestone and shales, are highly fossiliferous. On the shore south-east of Malahide similar strata appear, the low cliffs containing an abundance of corals, crinoids, and Brachiopods. In some beds near the second Martello tower from Malahide, bunches of coral, *Lithodendron junceum*, may be seen attached to a large bivalve shell, *Pleurorhynchus fusiformis;* other beds are full of *Spirifera bisulcata, Athyris planosulcata*, &c.

The old quarries inland—at Seamount, south of Malahide, and Feltrim to the south-west—have furnished a large number of species. Still further north, near the northern boundary of Sheet 102 Geological Survey Map, a little south of Skerries, a large quarry in the Lower Limestone has also yielded many fossils, amongst them being the large and beautiful univalve shell, *Platyschisma* (Turbo) *tiara*, a fossil which has also lately been collected by Captain Bennett, at Howth quarry, and Clare, Co. Kildare.

The following is a list of the quarries and other places in the County of Dublin where LOWER CARBONIFEROUS LIMESTONE fossils have been observed.† These localities are numbered,

* Explanation of Sheets 102 and 112, Geological Survey of Ireland, 1861, p. 7.
† Ibid. p. 13, &c.

corresponding numbers being placed opposite each species, in order to show where such fossils were collected, without repeating the names of the places where they occurred.

No. of Locality.	Situation and Sheet of Inch Map.
1.	"The Hoare Rock;" one and three-quarter miles west of Garristown; Sheet 101.
2.	Townland of Holmpatrick; rocks on shore, a little north of townland, south of Skerries boundary; Sheet 102.
3.	Oldtown; in the village; Sheet 102.
4.	Townland of Wolganstown; one mile and a-half south-west of Oldtown; Sheet 102.
5.	On the shore, about a furlong W.N.W. of Corballis House; Sheet 102.
6.	Seamount old quarries, about one mile south-east of Malahide; Sheet 102.
7.	Rocks on shore, E.S.E. of Malahide; Sheet 102.
8.	Quarries in the townland of Mitchelstown, three miles N.N.W. of Finglas; Sheet 102.
9.	Quarries at the village of Cloghran; Sheet 102.
10.	Townland of Dunsink; near Blanchardstown, Midland G. W. Railway; several localities near the Observatory; Sheet 102.
11.	Near Cappoge House; Sheet 102.
12.	The large quarries near St. Doulagh's; Sheet 102.
13.	On the shore near Howth Lodge, and quarry near Deer Park, to the south of it; Sheet 112.
14.	Rocks on shore at Balscaddan Bay; Sheet 112.
15.	Townland of Woodlands; near Lucan, several localities; Sheet 111.
16.	Townland of Woodville; E. of Clonsilla; Sheet 111.
17.	Townland of Astagob; a little N.E. of Lucan; Sheet 111.
18.	Quarries, S. of the village of Castleknock; Sheet 112.

List of the species of LOWER CARBONIFEROUS LIMESTONE Fossils, from the above localities.

PLANTÆ.

	Locality No.
Plant stem	7

CŒLENTERATA.

ACTINOZOA.—*Corals.*

	Localities.
Amplexus coralloides, . .	6, 10, 12, 15, 16, 17, 18.
Aulopora gigas, . . .	15.
Cyathophyllum Stutchburyi, .	7, 14.
Gorgonia Lonsdaliana, . .	6,
Lithodendron affinis, . .	13.
,, junceum, . .	6, 7, 14.

	Locality No.
Lithostrotion striatum, . . .	2.
Michelinea favosa, . . .	14.
Zaphrentis patula, ...	7, 14.
„ Phillipsi, ...	7, 15, 16.

MOLLUSCA.—*Polyzoa.*

Ceriopora interporosa, . .	14.
„ rhombifera, . .	7.
Fenestella antiqua, . . .	6, 7, 9, 10, 11, 13, 15, 16, 17, 18.
„ membranacea, . .	3, 6, 12, 17.
„ multiporata, . .	15, 18.
„ undulata, . . .	6.
„ varicosa ? . .	15.
Glauconome bipinnata, . .	6; 12.
„ gracilis, . . .	7.
Ichthyorachis Newenhami, .	7:
Polypora fastuosa, . . .	5.
„ verrucosa, . . .	6, 17.
Ptylopora flustriformis, . .	6.
„ pluma, . . .	10.
Vincularia dichotoma, . .	6, 10, 12, 15, 16, 17, 18.
„ multangularis, . .	12, 17.

Brachiopoda.

Athyris ambigua, . . .	6, 7.
„ lamellosa, . . .	7.
„ planosulcata, . . .	10, 15, 18.
„ Royssii, . . .	10.
Chonetes Hardrensis, . . .	8, 10, 15.
„ papilionacea, . .	2.
„ tuberculata, . .	12.
Discina nitida, ...	6.
Lingula mytiloides, . . .	15.
Orthis resupinata, . . .	1, 2, 6, 7, 10, 12, 15, 17, 18.
Productus aculeatus, . . .	3, 5, 6, 8, 9, 10, 12, 15, 17, 18.
„ cora, ...	2. 12, 17, 18.
„ giganteus, . . .	2, 10, 18.
„ longispinus, . .	7.
„ margaritaceus, . .	2, 18.
„ mesolobus, . .	6, 10, 12, 15, 18.
„ plicatilis, . . .	15.
„ punctatus, . . .	8.
„ scabriculus, . .	1, 2, 6, 7, 10, 12, 13, 16, 17, 18.

	Locality No.
Productus semireticulatus, .	1, 2, 3, 5, 6, 7, 8, 9, 10, 12, 13, 15, 16, 17.
,, undata, . . .	17, 18.
Retzia radialis ? . . .	6.
Rhynchonella pleurodon, . .	1, 3, 5, 6, 7, 10, 13, 18.
,, pugnus, . .	6, 10, 12, 15, 16.
Spirifera cuspidata, . . .	7.
,, duplicostata, . .	15.
,, glabra, . . .	2, 6, 7, 10, 12, 13, 14, 15, 18.
,, laminosa, . . .	7, 14.
,, lineata, . . .	2, 3, 6, 7, 10, 12, 13, 16, 17, 18.
,, pinguis, . . .	7, 9, 10, 12, 13, 15, 18.
,, rhomboidea ? . .	15.
,, striata, . . .	3, 6, 7, 10, 12, 13, 15, 16, 17, 18.
,, trigonalis, . . .	1, 2, 6, 15.
,, triradialis, . . .	6, 13, 15, 17.
Spiriferina cristata, . . .	6.
Streptorhynchus crenistria, . .	6, 7, 10, 12, 13, 15, 17, 18.
Strophomena rhomboidalis, . .	6, 7.
Terebratula hastata, . . .	1, 2, 3, 6, 8, 9, 10, 12, 13, 15, 17, 18.

Conchifera.

Arca semicostata, . . .	15, 16.
Avicula lævigata, . . .	17.
,, lunulata, . . .	6, 12.
Aviculopecten clathratus, . .	6.
,, concentricostriatus,	6, 18.
,, dissimilis ? . .	13.
,, fallax ? . . .	17.
,, flabellulus, . .	6, 12, 17.
,, flexuosus, . .	3.
,, Forbesii, . .	6, 10, 12, 15.
,, granosus, . .	6, 12, 15.
,, lævigatus, . .	6, 12, 18.
,, planicostatus, .	15.
,, quinquelineatus, .	8.
,, rigida, . . .	6, 18.
,, (Amusium) Sowerbii,	9, 10, 12, 18.
,, tessellatus, . .	6, 12.
Cardiomorpha oblonga, . .	6, 12, 17, 18.
Cucullæa obtusa, . . .	10.
Edmondia quadrata ? . . .	8.
,, sulcata ? . . .	17.

	Locality No.
Edmondia oblonga, . . .	11.
Leda, new species ? . . .	15.
Leptodomus fragilis, . . .	6.
Lima lævigata ?	12.
Lithodomus dactyloides, . .	?6, 15, 18.
? Myacites Omaliana, . .	17.
Pleurorhynchus aliformis, . .	?6, 13.
„ armatus . .	18.
„ fusiformis, .	7, 14.
„ Koninckii, n. s. (Baily) . .	14.
„ Hibernicus, .	6, 18.
Sanguinolites plicatus, . .	6, 10.
Pullastra bistriata, . . .	6, 12.
„ scalaris, . . .	6.

Gasteropoda.

Acroculia neritoides, . . .	17.
„ vetusta . . .	6, 12, 15.
Dentalium ornatum ? . . .	6.
Euomphalus Dionysii, . .	6.
„ pentangulatus, .	6, 7, 10, 12, 15, 18.
„ pileopsideus, . .	6.
„ serpula, . . .	2.
„ tabulatus, . .	6, 15, 18.
Loxonema Lefebvrei, . . .	13.
Macrocheilus ovalis, . . .	10, 15.
„ (Littorina) pusillus,	7.
Natica elliptica, ...	6, 12.
„ plicistria, . . .	6, 7.
Patella mucronata, . . .	6.
Platyschisma (Turbo) tiara, .	12, 27.
Trochella prisca, . . .	6, 12.
Turritella spiralis, . . .	3.

Nucleobranchiata.

Bellerophon tangentialis, . .	6

Cephalopoda.

Actinoceras giganteum, . .	? 12, 13.
Goniatites cyclobus, . . .	4.
„ furcatus, . . .	8, 10, 15, 16.
„ sphæricus, . .	10, 15.
„ „ var. obtusus,	15.
„ „ var. truncatus,	10.
Nautilus biangulatus, . .	12, 18.
„ (Discites) discors, . .	13.
„ dorsalis, . . .	10, 12, 13, 18.

	Locality No.
Orthoceras cinctum, . . .	30.
„ Goldfussianum, . .	10, 12, 15, 16, 17, 18.
„ Steinhauerii, . .	15, 18.

ANNULOSA.—*Echinodermata.*

Actinocrinus, stems, &c., . .	3.
„ polydactylus, .	7.
Crinoidea, species undetermined,	7, 8. 10, 12, 13, 14, 15, 17, 18.
Palæchinus, „ „ .	13.
Platycrinus lævis, . . .	7.
„ pileatus, . . .	15.

Annelida.

Spirorbis globosus, . . .	6.
„ intermedius, . .	6.

Crustacea.

Brachymetopus MacCoyi, . .	15, 18.
Cythere costata, . . .	18.
„ inflata, ...	3.
Entomoconchus Scouleri, . .	10, 12, 18.
Griffithides globiceps, . .	2, 3, 6.
Phillipsia Brongniartii, . .	13.
„ Derbiensis, . . .	2, 13, 15, 16.
„ pustulata, . . .	6, 8, 12, 15, 16, 17 18.

VERTEBRATA.—*Pisces.*

Chomatodus, palatal tooth, . .	2.
Cochliodus ?	7.
Psammodus, palatal teeth, . .	6, 7.

List of Fossil Localities, in UPPER CARBONIFEROUS LIMESTONE, County of Dublin.—(Continued from p. 86.)

19. Townland of Tobergreggan; three-quarters of a mile south of Garristown, junction beds of Upper Limestone and of coal measures; Sheet 101.
20. Townland of Westown; in bed of river Delvin, at Ford of Fine; Sheet 102.
21. Townland of Balrickard; quarry by roadside, half-a-mile S. of Bog of the Ring, junction of Upper Limestone and coal measures; Sheet 102.
22. Townland of Courtlough; quarry close to road, three-quarters of a mile N.W. of Man-of-War, junction of Upper Limestone and coal measures; Sheet 102.
23. Townland of Loughshinny; on the shore at the village; Sheet 102.

24. Townland of Lougshinny; on the shore, about a furlong S. of the village, junction of Upper Limestone and coal measures; Sheet 102.
25. Townland of Blanchardstown; quarries and cuttings, E. and S. of the village; Sheet 112.
26. One mile and a-half S.W. of Lucan, by roadside; Sheet 111.
27. Cursis-stream quarry, about two miles east of Lucan; Sheet 111.
28. In stream, a little north of Clondalkin village; Sheet 111.
29. Quarry, between road and Tolka river, a quarter of a mile W. of Finglas Wood bridge; Sheet 112.
30. Townland of Butcher's Arms; one mile W. of Golden Bridge; Sheet 112.
31. Townland of Golden Bridge; quarry near Blackhorse Bridge; Sheet 112.
32. Railway cutting and quarry at Killester; Sheet 112.
33. Quarries, S. of road at Greenoge; Sheet 111.
34. About one mile S.E. of Castle Bagot, two and a-half miles S.W. of Clondalkin; Sheet 111.
35. Road cutting and quarries, S. of Corkagh, about one and a-half miles S. of Clondalkin; Sheet 111.
36. Between Corkagh Mills and Belgard Castle; Sheet 111.
37. Newland's Demesne; about a quarter of a mile N.W. of Belgard Castle; Sheet 111.
38. Townland of Garranstown; about a furlong W. of Kilnamanagh House, and one mile S.E. of Clondalkin; Sheet 112.
39. One field, S.E. of Kilnamanagh House; Sheet 112.
40. Quarries, S. of Mount St. Joseph's Monastery, Clondalkin; Sheet 112.
41. Townland of Bushelloaf; a little E. of last locality; Sheet 112.
42. Quarries, near the Red Cow, one mile E. of Clondalkin; Sheet 112.
43. Boundary of Townlands, near the Red Cow; Sheet 112.
44. Near Ballymount Little, one and a-half miles S.E. of Clondalkin; Sheet 112.
45. Between preceding locality and Air Mount; Sheet 112.
46. Quarries, S.E. of Cromwell's Fort, near Crumlin; Sheet 112.
47. Quarries on both sides of the road, S. of Kimmage; Sheet 112.
48. Old quarries, between the townlands of Green Hills and Limekiln Farm, S.W. of Crumlin; Sheet 112.
49. In river Dodder, at Terenure; an old quarry at Rusina Ville; Sheet 112.
50. Quarries, S.E. of R. C. Chapel, Crumlin; Sheet 112.
51. Quarry, by Methodist Chapel, Donnybrook, E.; Sheet 112.
52. In river Dodder, near Milltown; Sheet 112.
53. Large quarry at West Hampton, N. of Roundtown; Sheet 112.
54. In river Dodder, S. side, near Donnybrook; Sheet 112.
55. Quarry on N. side of river Dodder, opposite cloth mill, Rathmines Great; Sheet 112.

List of FOSSILS from UPPER CARBONIFEROUS LIMESTONE, at the above places.

PLANTÆ.

	Locality No.
Plant stems, ...	*21, *24, 27, 31, 32.

ACTINOZOA.—*Corals.*

Amplexus coralloides, . .	26, 35, 50.
Cladochonus crassus, . . .	24*.
Cyathophyllum, (undetermined species), ...	33, 35, 40, 41, 46, 51, 53.
Lithodendron junceum . .	47.
Lithostrotion striatum, . .	20.

MOLLUSCA.—*Polyzoa.*

Ceriopora rhombifera, . .	24*.
Fenestella antiqua, . . .	11, 23, 24*, 26, 36, 52.
„ membranacea, . .	26.
Polypora fastuosa, . . .	22.
Vincularia dichotoma, . .	22.

Brachiopoda.

Chonetes Hardrensis, . .	24*, 28, 31, 35, 40, 43, 48, 54.
„ papilionacea, . .	35, 36, 37, 40, 41, 43, 44, 45, 46, 52, 53, 54, 55.
Discina nitida, ...	22, 23, 46.
Lingula mytiloides, . . .	33.
Orthis resupinata, . . .	22, 23, 24*, 29, 30, 33, 35, 36, 40, 41, 43, 44, 45, 46, 47, 49, 50, 51, 52, 54, 55.
Productus aculeatus, . . .	35, 40, 43, 45, 46, 50, 54, 55.
„ cora, ...	46.
„ gigantea, . . .	35, 46, 47.
„ longispina, . . .	46, 53.
„ margaritacea, . .	53.
„ punctatus, . . .	43, 45, 48, 54.
„ scabriculus, . .	22, 23, 24*, 26, 33, 34, 35, 36, 40, 41, 42, 45, 46, 54.
„ semireticulatus, . .	20, 22, 23, 24*, 33, 35, 36, 38, 40, 41, 42, 43, 45, 47, 48, 52, 53, 54, 55.

* Junction beds of Upper Limestone and coal measures.

	Locality No.
Rhynchonella pleurodon, . .	22, 23, 24*, 32, 34, 35, 41, 51, 52, 53.
„ pugnus, . .	23.
Spirifera trigonalis, . . .	22, 23, 35, 46, 53.
„ convoluta, . . .	22.
„ glabra, . . .	? 19*, 22, 23, 24*, 33, 38, 41, 43.
„ lineata, . . .	22, 23, 24*, 33, 35, 36, 46, 48, 53, 54, 55.
„ pinguis, . . .	26, 35.
„ striata, . . .	24*.
„ triradialis, . . .	45.
„ insculpta, . . .	24*.
Streptorhynchus crenistria, . .	22, 23, 24*, 36, 39, 41, 44, 46, 47, 53, 55.
Strophomena rhomboidalis, .	23, 24*.
Terebratula hastata, . . .	22, 23, 35, 48, 50, 55.
„ „ var sacculus,	23.
„ vesicularis, . .	52.

Conchifera.

Aviculopecten Forbesii, . .	47.
? Donax primigenius, . . .	29.
Lithodomus dactyloides, . .	39.
Posidonomya Becheri, . .	19*, 21*, 22*, 24*, 39.
„ „ var membranacea, ...	28.

Gasteropoda.

Euomphalus Dionysii, . .	45.
„ pentangulatus, . .	20, 26.
„ pileopsideus, . .	35, 36, 45, 46, 55.
Loxonema (species undetermined),	36, 42, 45, 55.
Macrocheilus do.,	42, 48.
Natica plicistria, . . .	11.
Pleurotomaria (species undetermined), ...	46, 55.
Turritella spiralis, . . .	45.
„ tenuistriata, . .	23.

Nucleobranchiata.

Bellerophon hiulcus, . . .	45.

Cephalopoda.

Goniatites furcatus, . . .	25.
„ sphæricus, . . .	19*, 21*, 22, 24*, 31, 32, 35, 36, 48, 53.
Orthoceras Steinhauerii, . .	16*.
„ (species undetermined)	21*, 22, 28, 29, 41, 48.

ANNULOSA.—*Echinodermata.*

	Locality No.
Archæocidaris Urii (plates), .	24*.
Crinoidal remains, . . .	22, 24*, 26, 28, 29, 32, 34, 36, 40, 41, 42, 44, 45, 46, 48, 49, 51, 52, 53, 54, 55.

CRUSTACEA.

Cythere (species undetermined), .	54.
Griffithides globiceps, . . .	24*, 33, 34, 35, 55.
Phillipsia Brongniartii, . .	34.
„ Derbiensis, ...	23, 36, 43, 44, 45, 53.
„ pustulata, . . .	20, 35, 40, 46.
„ (species undetermined),	54.

PISCES.

Cochliodus? palatal tooth, . .	46.
Fish scales, ...	35.

What were formerly considered to be lower coal measure shales are in the second edition of the Explanation to sheets 102 and 112 of the Geological Survey of Maps (1875), called "Upper Shales," but as they contain a distinct and characteristic assemblage of fossils corresponding with those of the basal shales of the coal measures of Kilkenny, Queen's County, Tipperary, Limerick and Clare, the original designation is retained. Three distinct patches of these basal shales occur in the north of Dublin, near Garristown, the Naul and Westown, extending east of the "Man-of-War;" a second at Featherbed-lane station, Baldongan; and the third on the sea-shore at Loughshinny, between Rush and Skerries. The shales of these places are, in many instances, full of fossils, mostly marine shells such as *Aviculopecten papyraceus Posidonomya Becheri* and *P. membranacea*, *Goniatites sphæricus* and *Orthoceras Steinhauerii.* With these are occasionally associated fish remains and a few fragmentary stems of fossil plants. At some of the localities junction-beds between these coal measure shales and the limestone may be observed. These junction-beds in the list of species are marked with an asterisk

List of Fossil Localities in Lower Coal Measure Shales.

56. A little north of the village of Garristown.
19. Townland of Tobergreggan; junction-beds mentioned in previous list.
57. Do., one mile and a-half W.S.W. of Garristown.
58. Townland of Westown; quarry a little S. of the wood.
59. „ of Knockbrack; small quarry in the glen.
60. „ of Kitchenstown; in a ditch S. of the road.
61. „ of Belgee; quarry a little S. of the cross-roads.
21. „ of Balrickard; junction-beds mentioned in previous list.
62. „ of Courtlough; quarry close to road about three quarters of a mile N.W. of "Man-of-War;" upper part coal measures.
24. „ of Loughshinny; junction-beds mentioned in previous lists.

List of Fossils from Coal Measure Shales at the Above Places.

Plantæ.

Calamites cannæformis, . .	58.
Plant stems (undetermined), .	58, 59.

Mollusca: *Conchifera.*

Aviculopecten papyraceus, . .	56, 58, 59.
„ variabilis, . .	58, 62.
Lunulicardia (species undetermined),	58.
Posidonomya Becheri, . .	60, 61, 62.
„ membranacea .	56, 57, 58, 59, 62.

Cephalopoda.

Goniatites sphæricus, . . .	56, 57, 58, 59, 61.
Orthoceras Steinhauerii, . .	56, 57.
„ (species undetermined),	56, 57, 58, 62.

Echinodermata.

Crinoidea (stems and joints), .	58, 59.

Crustacea.

Dithyrocaris (species undetermined), 58.

The Secondary and Tertiary Rocks are entirely absent from this district, with the exception of the Pleistocene or Glacial Drift, which extends over the northern portion. Southwards of Malahide this more ancient deposit, called the "Lower Boulder Clay,"* "becomes covered by the sand and gravel deposit which on the higher

* Explanation to sheets 102 and 112, 2nd edition (1875), p. 67.

grounds formed of the granite and slate is alone present." Various observers have described this more recent deposit, which on the eastern summit of Mount Pelier is found at an altitude of 1,235 feet above the sea, and on the western side of the Three Rock Mountain at an elevation of 1,200 feet.

Marine shells of existing species have lately been found by the Rev. Maxwell H. Close, near Caldbeck Castle, on Kilmashogue Mountain, at an elevation of a little over 1,200 feet, from a gravel and sand pit (the " limestone gravel" of Ireland). The following were collected :—*

Fusus ? part of columella.
Cardium echinatum.
Cyprina Islandica.
Venus striatula.
„ casina ?
Mactra stultorum, with perforations made by a small shell-boring Annelid.

At Ballyedmonduff, on the S.E. side of the Three Rock Mountain, on the road leading from Stepaside to Glencullen, at an elevation of 1,000 feet, from a similar gravel pit, " chiefly composed of clean stratified gravel and sand," the same gentleman collected the following shells, &c. :—

Trophon muricatus.
Fusus ? part of columella.
Turritella communis.
Ostrea edulis.
Pecten (two species).
Cardium edule.
„ echinatum.
Astarte compressa.
„ elliptica.
„ sulcata.
Cyprina Islandica.
Artemis lincta.
Venus striatula.
„ casina.
Lutraria elliptica.
Mactra stultorum ?
Tellina ?
Mya truncata ?
Pholas crispata.
Balanus balanoides and perforations ascribed to a small shell-boring Annelid.

* Journal of the Royal Geological Society of Ireland, vol. iv., part 1., new series, p. 36, etc.

Fragments of shells were also observed at other places on the Dublin Mountains in similar deposits, the particulars of which are described by the Rev. M. H. Close in the article referred to.

Fragments of marine shells have also been collected from coarse sand a little to the east of Glennasmole, Townland of Corrageen, at about 600 feet above the sea level,* and form a conglomerate of drift pebbles, cemented together by Arragonite (Carbonate of Lime) a little south of Fort or Bohernabreena bridge.

At Howth marine shells have been collected and described by Dr. Scouler from the gravel deposits there,† and Dr. Oldham gives a list of others from similar deposits at Killiney, in the County of Dublin, and Bray, County of Wicklow.‡

The following species were identified by Dr. Scouler from Howth:—

Turritella (terebra) communis.
(Turbo littoreus) Littorina littorea (Periwinkle.)
(Nerita littoralis) Littorina littoralis.
Buccinum undatum.
Cardium edule.
Cyprina Islandica.
Pecten varius.

Those named by Dr. Oldham from Killiney, &c., being—

Ostrea edulis.
Tellina solidula.
Pecten opercularis.
Pullastra decussata.
Nucula oblonga.
Astarte (Gairensis) elliptica.
Corbula nucleus ?
Saxicava rugosa.

The only remaining fossils to notice are those of Mammalia, found in Pleistocene deposits of freshwater shell marl immediately below the Peat Bogs.

The great Irish deer, *Megaceros Hibernicus*, so frequently found in these deposits in Ireland, evidently existed formerly in considerable numbers in the neighbourhood of Dublin. Professor Oldham, in a paper read before the Geological Society of Dublin, in 1847,§ records the discovery of the remains of at least thirty

* Journal Geol. Soc. of Dublin, vol. vi., p. 144. † *Ibid*, vol. i., p. 270.
‡ *Ibid*, vol. iii., p. 69. § Journal Geol. Soc. of Dublin, vol. iii. 280 (1848.)

individuals, accompanied by the head and antlers, with other bones of a Rein Deer, *Cervus Tarandus*, in the cutting for a drain at Ballybetagh Bog, Kiltiernan, County Dublin, near the boundary of the counties of Dublin and Wicklow (sheet 121, maps of the Geological Survey of Ireland).

Dr. A. Carte also gives in a paper read before the same Society *—an account of a skull and antlers of a Rein Deer found on the verge of the Curragha Bog, in the parish of Ballymadun, near Ashbourne, County Dublin (sheet 101 Geological Survey Maps). This fine example, now in the Royal Dublin Society's Museum, was found in a very similar deposit to that previously mentioned—namely, imbedded in marl and clay, under a thickness of four or five feet of peat.

From the peculiar shape of the brow antler, which forms a broad vertical plate, centrally situated in front of the head, these specimens are proved to belong to the Caribou, or barren ground variety, now inhabiting America, between the 63rd and 66th degrees of north latitude, in the winter, and migrating to the coasts of the Arctic Sea in summer. It becomes, therefore, very interesting to meet with evidence of the former existence of this variety of the Rein Deer in Ireland.

* Journal Geol. Soc. of Dublin, vol. x., p. 103 (1863-4.)

VIII.—ON THE BARYTES MINES NEAR BANTRY.

BY

EDWARD T. HARDMAN, F.C.S., of the Geological Survey of Ireland.

[Read January 21st, 1878.]

SULPHATE of Barytes or Heavy Spar is a mineral of not very common occurrence in Ireland, and is only met with in a few localities in sufficient quantity to be of commercial value. In various places in the county Cork it is found in some abundance; and near Bantry it has been, and I believe is at present, being extensively worked. Having visited these mines some time ago, I propose giving a brief description of them.

The most extensive lode is met with in the townland of Derry-ginah, Middle, about two miles east of Bantry. It bears nearly due east and west, N. 80° E. & S. 80° W.; cutting the strike of the Old Red Sandstone slates, at an angle of about ten to fifteen degrees. The lode is ten to fifteen feet thick, and has been followed for some 200 or 300 yards, the workings extending to a depth of about fourteen fathoms. About one-third of the lode in the centre consists of extremely pure Barytes, but the sides of it consist of an impure variety called cawk, which contains a quantity of quartz, carbonate of lime, green carbonate of copper, Peacock copper ore, and micaceous or specular iron. The last is found in considerable quantity—so much so, that the manager of the works was of opinion it might prove commercially valuable could it be smelted.

Besides the difference in purity of the Barytes, two varieties occur in this lode. One a crystalline glassy-looking specimen; the other a granular saccharoidal variety, and the last is the kind most valued, as it is the most easily ground in the process of preparation.

From this mine a considerable quantity of mineral has been obtained and exported by the Bantry Barytes Mining Company, who are now working it. When in full work they can easily turn out twenty tons per day. But the mine is capable of yield-

ing a much larger quantity, being in fact so far only limited by the amount of labour obtainable, and the state of the market. Owing to the cost of carriage also, the price of the mineral is necessarily rather high.

The next locality for Barytes is a little more than mile south-east of Bantry, in the townlands of Ardargh and Darreengreanagh, and so far as I know of, has not been mentioned in any list of localities of that mineral; although the occurrence of the lode is marked in the field maps of the Geological Survey. And the mode in which it occurs is sufficiently curious to deserve a passing notice.

This deposit occurs in similar grits and slates to those inclosing the first named, but instead of forming a lode it consists of a thick pipe-like mass of nearly pure Barytes. This pipe is about thirty feet long, and fifteen wide, and it has been proved to extend downwards for at least ninety feet, having been entirely excavated to that depth. At the corners it throws off small branches or veins, from two to five feet thick, and some of these have been found at the surface some distance from the main body, but appear to thin away on every side.

This great mass is almost entirely composed of the very purest sulphate of Baryta. An analysis of it showed it to contain over ninety-five per cent. of sulphate. The "seconds" or "cawk" (which forms but a very small proportion of the lode, being principally confined to the walls), contain various copper ores, the green carbonate, Peacock ore, and copper pyrites, as well as galena, all in very small quantity. The walls of the lode are coated in some places with steatite, or chlorite. The rocks enclosing it strike N. 80° E., with a high dip of 75° to 80°.

This deposit has been worked for a considerable time by the Scart Barytes Mining Company, and the principal mass of ore has been removed to the depth above stated—ninety feet.

There is always an amount of mystery kept up as to the uses for which Barytes is intended, arising from the fact that it is chiefly in demand for purposes of adulteration, its high specific gravity being taken advantage of. Thus it is principally in request for the adulteration of white lead and other paints; and some even say that it is employed as a commercial substitute for

sugar. Such at least is the Bantry native opinion. It is besides occasionally useful for the manufacture of glazes for porcelain.*

The mineral is worth about £1 per ton, delivered free on board at Bantry, but when ground and prepared it fetches £4 per ton.

A few words on the probable mode of formation of this mineral may not be out of place. And first I may mention that many of the Irish localities for veins of sulphate of Barytes appear to lie in the Old Red Sandstone. Thus Portlock records its occurrence in the Old Red Sandstone of Ballynascreen and Desertlyn, county Derry, and Clogher, county Tyrone. But this is merely a coincidence, because it is found here as in other counties in many other rocks, crystalline and sedimentary, and in England it occurs largely in the Carboniferous limestone. Now it is tolerably easy to account for the presence of veins of this mineral in limestone, which is easily soluble and quickly worn into fissures or pipes by ordinary atmospheric water, in which, under some circumstances, Barytes might be deposited, but the first difficulty with which we have to contend in this case is the solution of such rocks as sandstone and slate. The Derryginagh deposit can be accounted for by a simple fissure, but this will not account for the other case, in which the original material has been removed in the form of a nearly square pipe, which could never have been produced solely by fissuring. There can be no doubt but this receptacle has received its present form through the action of water. Doubtless such pipes are due to fissures in the first instance which, allowing the water to percolate freely, are eaten away bit by bit into their present form.

Age of these Veins.—As these veins run partly along and partly across the strike of the strata, which lie in flexures dipping at high angles, it follows that they must be of more recent date than that of the upheaving and flexuring of the Old Red Sandstone and Carboniferous rocks of the south of Ireland. Now, as Professor Hull has shown, these flexures are due to forces acting at the close of Carboniferous and previous to the Permian Periods.† It

* It appears to me that the granular varieties might, with advantage, be substituted for alabaster, for statuary and ornamental purposes. The mineral can be obtained in large blocks.

† Jour. Roy. Geol. Soc., Ireland, iv., pt. iii., p. 114.

is certain therefore that these lodes, as well as the copper lodes of the other parts of Cork as well as Kerry, are younger than the Carboniferous period, and may be therefore about the same age as those of Cornwall. It is, of course, impossible to determine at what period post the Carboniferous they have been deposited, since there are no newer strata in this part of Ireland; but however this may be, we may suppose that the original fissures were most likely opened during the disturbances which produced the flexures of the Old Red Sandstone in the south-west of Ireland.

Deposition of the Barytes and associated Minerals.—Barytes being one of the most insoluble substances known, it is unlikely that it could have been deposited from solution in cold water; on the other hand it is so very infusible that the heat necessary to reduce it to a plastic condition would be more than sufficient to melt the surrounding rocks. Its deposition is therefore to be ascribed with most probability to the action of thermal springs, the waters of which were forced upwards into these fissures, while the strata at present exposed were still buried under a great mass of superincumbent rocks. The waters at first warm enough to hold small quantities of such difficultly soluble minerals in solution would, as it came nearer the surface, become somewhat cooler, and these minerals would be then deposited along the sides of the fissure. This point, which is insisted on by Delesse, is demurred to by Bischof, who considers that the waters of ascending hot springs cannot produce these deposits, but it is evident he left out of consideration the cooling of the water as it rose.

Source of the Sulphate of Barytes.—This is to be sought for either in the immediately outlying or surrounding rocks, or in masses of rock at some distance, from which some compound of barium may be carried down into springs. Carbonate of barium is by no means an uncommon mineral, and barium in some form is of common occurrence in minute proportion in limestone. Silicate of barium is also found occasionally in igneous rocks, and might, therefore, also occur in parts of the Old Red Sandstone which are derived from the debris of such rocks*. Those com-

* The very small quantity of Barium compounds disseminated through rocks, is of little moment in this consideration. As Bischof well remarks, the minimum quantities in rocks may become the maximum quantities in lodes.

pounds of barium are to a small extent soluble in water, and would be brought down through the strata to rise again from deep-seated springs. Meeting now with soluble sulphates, these salts of barium would be converted into sulphate, and as the water cooled in rising to the surface, this would be deposited. As a matter of fact crystals of sulphate of barium have been found on the granite of Carlsbad, where a hot spring, containing in solution traces of that substance, burst out. Chloride of barium is sometimes noticed in spring waters, and this would also give rise to sulphate in the manner pointed out.

In fact it is only through the medium of hot water that the sulphate of Barytes of Bantry, and the very insoluble minerals associated with it, can be supposed to have been deposited.

IX.—NOTE ON A NEW GEOLOGICAL MAP OF IRELAND, BY PROFESSOR HULL, F.R.S., DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND.

[Read May 20, 1878.]

In presenting a copy of his new Geological Map of Ireland, Professor Hull stated that although on the same scale as that of the late Professor Jukes (about eight miles to the inch), and in many respects resembling it, the new map had been entirely re-engraved. Owing to the progress of the Geological Survey since Professor Jukes' map was published (1867), and an advance in our knowledge in some respects, several alterations (which the author hoped would be considered improvements) had been introduced. The following were the more important:—

1st. In the metamorphic districts of Donegal, Mayo, and Galway, the great beds of quartzite, which form many of the higher elevations, and some of the beds of limestone had been introduced. In this respect the new map resembled that of Sir Richard Griffith, to which the author was indebted for being able to insert the quartzites and limestones of Donegal.

2nd. The next point of importance was the colouring of the mountainous districts of Iveragh and Dunkerron, lying to the south of Dingle Bay, and of the promontory between Kenmare Bay and Bantry Bay. The former included the Reeks and Killarney Mountains; the latter those of Caha and Slieve Miskish. On Griffith's map, the rocks composing these ranges (except near their margins where they pass below the Lower Carboniferous beds) are coloured in the same way as "the Dingle Beds" of the promontory of Dingle, being considered identical in age. On the maps of the Geological Survey, and of Professor Jukes, on the other hand, the highlands of Kerry are coloured Old Red Sandstone. In the Dingle promontory, as is well known, this formation rests on "the Dingle Beds" in a highly discordant manner; while in the districts south of Dingle Bay, no apparent unconformity exists, according to the observations of the Geological Surveyors;

and as it was found impossible to draw a boundary between these beds and the Old Red Sandstone, the whole of the beds were massed under the colour of this latter formation. In both districts, however, viz., those north and south of Dingle Bay, a separation has been made on the map of Sir R. Griffith; and as the author concurs with the view adopted by that eminent authority, and can have no doubt but that the greenish grits and green and red slates of the Reeks and Killarney Mountains are the actual representatives of the "Dingle beds," he has followed Sir R. Griffith's map in this instance also. The author does not offer any opinion on the age of "the Dingle beds," though inclining to the view that they are Upper Silurian; nor does he think that much reliance can be placed on the divisional line between these beds and those of the Old Red Sandstone in the promontories north and south of Kenmare Bay.*

3rd. The third alteration refers to the Carboniferous districts. On Jukes' map the whole of the beds above the Carboniferous limestone are represented under one dark colour, as "Coal-Measures." On the new map an attempt has been made to represent at least three divisions in this group—1. The "Yoredale shales;" 2. "Millstone grit;" and 3. Lower and middle Coal-Measures. The progress of the Government survey has rendered this possible in all the Carboniferous districts but those of the S.W. of Ireland, where the details are not yet worked out, and where consequently the divisions are only tentative.

4th. Lastly, in representing the trap rocks, whether contemporaneous or intrusive, an attempt has been made to separate, and show by distinct colours, the pyroxenic from the felspathic—the former including diorite ("greenstone"), dolerite, basalt, &c., the latter including quartziferous porphyry, felstone porphyry, felstone, trachyte, &c. Many of the principal faults are shown by white lines.

* Since the above was written, the author, having visited these districts, has come to the conclusion that the Old Red Sandstone is absent in some places.

X.—THE OLD RED SANDSTONE (SO CALLED) OF IRELAND IN ITS RELATIONS TO THE UNDERLYING AND OVERLYING STRATA, BY G. H. KINAHAN, M.R.I.A., &c. [ABRIDGED.] WITH PLATES 1 AND 2.

[Read November 18, 1878.]

A QUARTER of a century ago it was a disputed question whether the "Old Red Sandstone" was a separate formation or not; about that time, or a few years later, the subject engaged the attention of the Geological Section of the British Association. It would seem that, as far at least as the Irish Old Red Sandstone is concerned, a decidedly negative answer must be given to the question.

The argument consists of two divisions, viz.:—

(1). There is a wide unconformability between what have been regarded by some as the lower and the upper portions of this supposed formation; while the lower is joined conformably to the underlying Silurian,* and the upper is similarly connected with the overlying Carboniferous strata. The lower part is, in fact, Silurian and the upper is Carboniferous.

(2). The "Old Red Sandstone" beds, though usually below the base of the Carboniferous strata, are not always so, but are, in various places, on the horizons of different parts, sometimes upper parts of the Carboniferous Limestone, and are sometimes actually interstratified therewith.

(1). The former of these arguments involves the necessity of a short historical sketch of the controversy respecting the age of the rocks in certain districts of Ireland.

When I joined the Geological Survey, Sir R. Griffith had mapped the older rocks in West Cork as of Silurian age; while Jukes was inclined to class them as "Old Red Sandstone." Plant remains were found in rocks of the same series in the Killarney district, in the summer of 1855, and farther westward near Valencia, in the following year, by the fossil collector, C. Galvan.

* It should be borne in mind that "Cambro-Silurian" and "Silurian" mean respectively, in this paper, the formations usually called Lower Silurian and Upper Silurian.

When the plants were pronounced by Salter to be of Carboniferous types* Jukes considered the question to be finally settled. Griffith, however, said "Wait until the Dingle district is examined and you will find that although the plants may be of Carboniferous types the rocks are Silurians."

When the Dingle peninsula was examined by Du Noyer, Foot, and Wynne, it was found that, while there was a great unconformability between the lower and upper divisions of the strata called Old Red Sandstone, a complete conformability extended from the lower division downwards into fossiliferous Silurians, and from the upper division, upwards, into the Carboniferous Limestone, and thence into the Coal Measures. In the lower division, however, no fossils† could be found; and those strata were called "Dingle Beds," a title which involved no assumption as to their age. To this lower division, according to both Griffith and Jukes, the first mentioned rocks near Killarney, near Valencia, and in West Cork belong.

Subsequently these rocks were examined by Griffith, Murchison and Jukes conjointly; and some of the party visited not only Cork and Kerry but also Galway and Mayo. After this exploration Murchison was inclined to side with Griffith, notwithstanding the difficulty presented by the plant remains.

But on the other hand, the late Mr. John Kelly showed that the Dingle Beds have the same stratigraphical position as the rocks mapped as Old Red Sandstone in the Curlew and Fintona mountains; while the latter are lithologically similar to the Old Red Sandstones of the Commeragh and Knockmealdown Mountains and the Galtees. The classification of the just mentioned Cork and Kerry rocks was therefore left an open question, until the rocks in Mayo, Roscommon, Sligo, Fermanagh, and Tyrone, suggested by Griffith to be of the same age as the Dingle Beds, were examined.

Jukes, as a believer in the "Old Red Sandstone" formation, could scarcely act otherwise; for, as he said at the time, "If you make the Dingle Beds Silurian you do away with the Old Red Sandstone."

* Baily agrees in this opinion.

† I have since learned from Mr. O'Kelly that fossils like plant stems were subsequently found in the Dingle beds.

The question remained in abeyance while the officers of the Geological Survey were examining the rocks of north-east Munster; until about 1864, when Foot declared that he suspected the rocks of the Curlew Mountains to be "Dingle Beds." The following year Jukes examined these rocks for himself, and subsequently announced his belief that the lower portion of the so-styled Old Red Sandstone near Ballaghaderreen, a dozen miles or more W.S.W. of the Curlew Mountains was probably of the same age as the Dingle Beds; since it seemed to lie conformably on similar fossiliferous Silurians, as previously stated by Kelly, while it was similarly capped unconformably by what all would regard as true Old Red Sandstone [Carboniferous].

Still it was premature to say what its age might be, until it and all the tracts mentioned by Griffith had been systematically examined.

At this time I began the work in West Galway and Mayo; and after seven years careful examination I came to the conclusion that the oldest rocks there are Cambrians.

These are partially covered, as it would seem, conformably, by Cambro-Silurians. I found that resting unconformably on both of these are newer rocks; some of which, years ago, were proved by their fossils to be Silurians, but others of which for a time were considered to be Old Red Sandstone. All of these are capped unconformably by the acknowledged Old Red Sandstone [Carboniferous].

The rocks extending from Loughs Corrib and Mask, by Maum, to the Atlantic, on the south of Killary Harbour, had for years been known to be Silurians; but the rocks between Toormakeady, on Lough Mask, and Mweelrea, north of the mouth of Killary Harbour, as also an isolated tract farther north near Louisburgh, were at one time supposed, on account of their lithological character, to be Old Red Sandstone. Griffith, however, found Silurian fossils at Toormakeady, while subsequently I found such, in somewhat similar rocks, in the Mweelrea Mountains. It was either during the exploration in which Griffith found the fossils at Toormakeady, or on a subsequent occasion, that he came to the conclusion that all were of Silurian age; the Louisburgh beds being the newest, and representatives of a portion of the Dingle Beds.

To the northward of Toormakeady, in the neighbourhood of Croaghmoyle, there is a large tract of rocks that Jukes, Symes

and myself were convinced must be of about the same age as the Toormakeady conglomerates, although it was marked in Griffith's map as Old Red Sandstone. This led me to seek for an explanation; and when my maps and sections were so far complete as to be intelligible they were carefully examined and considered by Griffith. Subsequently I waited on him by appointment, and in our conversation I learned that the marking of that district, as also of others on his map, as Old Red Sandstone, was done in compliance rather with received opinion than with his own conviction. That in the so-called "Old Red Sandstone" formation in Ireland there is a marked unconformability, while part of it extends downwards conformably into the Silurians, and part of it upwards similarly into the overlying Carboniferous rocks. That the rocks of West Cork and adjoining portion of Kerry, of Dingle, of Toormakeady, of Mweelrea, of Louisburgh, of Croaghmoyle, of the Curlew and Fintona Mountains were as he believed of nearly similar Silurian age. That those in West Cork and South Kerry, Dingle, Toormakeady, Mweelrea and Louisburgh he had had time to examine properly and had mapped them as Silurians; that the rest had not been so carefully examined by him, but that in deference to Portlock's authority and also because they were lithologically more or less similar to the Old Red Sandstone [Carboniferous] of the Knockmealdowns, the Galtees, and the Commeragh Mountains, he had left them as Old Red Sandstone. But at the same time he pointed out "the Toormakeady conglomerates are also similar, yet I found Silurian fossils in them."*

In this conversation he also stated "None of my work is guesswork; all my conclusions are from personal examination. I cannot now work these rocks out, and my map must remain as it is; the Geological Survey must finish the examination," or words to that effect.

After this interview I paid more special attention to this subject,† and an epitome of the results of my researches (except in respect to the equivalents of the Dingle Beds) appears in the recently published "Manual of the Geology of Ireland." In that

* Strictly these fossils are not in the conglomerates, but in the beds *below* them. As yet, in no place above the Toormakeady conglomerate, have fossils been found; except, perhaps, in the green tuff at Mount Partry—its position however is uncertain.

† Previously Foot and myself, in about 1864, had written a paper to show that the Munster Old Red Sandstone was in part Silurian, and in part Carboniferous. This paper, however, was not published, as Jukes considered it premature.

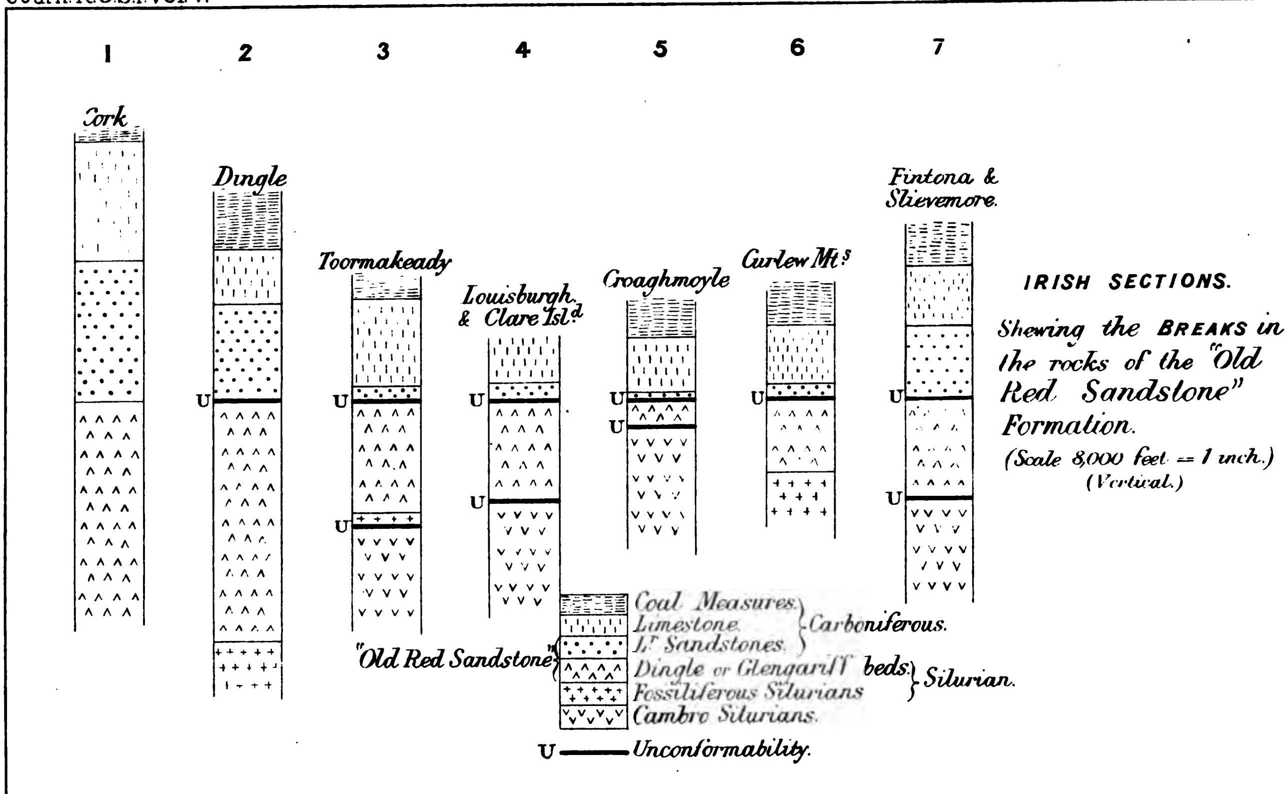
book I only hint at the age of the equivalents of the Dingle Beds, because at the time it was being written, more than a year ago, I was aware that some of my colleagues were engaged working out the disputed rocks in the Curlew and Fintona Mountains, and I supposed they would have given attention to the controversy concerning their age. It was not until the book was in print that I learned that that dispute had been ignored; although Mr. Berdoe-Wilkinson's work proved that Jukes' and Foot's surmises in respect to the classification of the rocks of the Curlew Mountains were correct. Then when I felt at liberty to express my opinion, it was too late to do so, except in the preface of the book.

Hitherto I have only given a short sketch of the controversy respecting the rocks in the various districts mentioned. I shall now give a recapitulation of the results which are represented diagrammatically in Plate 1.

SECTION I.—In West Cork, and Kerry south of Dingle Bay the "Old Red Sandstone" (Carboniferous) rests conformably on the "Glengariff Grits," which, as already mentioned, were considered by Griffith and Jukes to be the equivalents of the "Dingle Beds," (the opinion of such geologists on such a point is scarcely to be questioned) and by Griffith to be Silurians. The conformability and continuity in this section are quite exceptional and very remarkable. Either there has been an interesting difference in the geological histories of this district and of the neighbouring Dingle Promontory, the relations between the respective phenomena being partially caused by an intervening line of weakness afterwards marked by the great post-Carboniferous fault that extends along the south side of Dingle Bay and the valleys of the Flesk and Blackwater, and partially concealed by that fault; or the continuity may possibly (though not probably) be only apparent.

SECTION II.—This shows the relations of the strata in the Dingle Promontory and its neighbourhood. The wide unconformity between the "Dingle Beds" and the "Old Red Sandstone" (Carboniferous) is indicated at U; a similar break is shown in the corresponding place in all the following sections.

SECTION III.—At Toormakeady, Co. Mayo, are conglomerates that probably represent the lower portion of the Dingle Beds;



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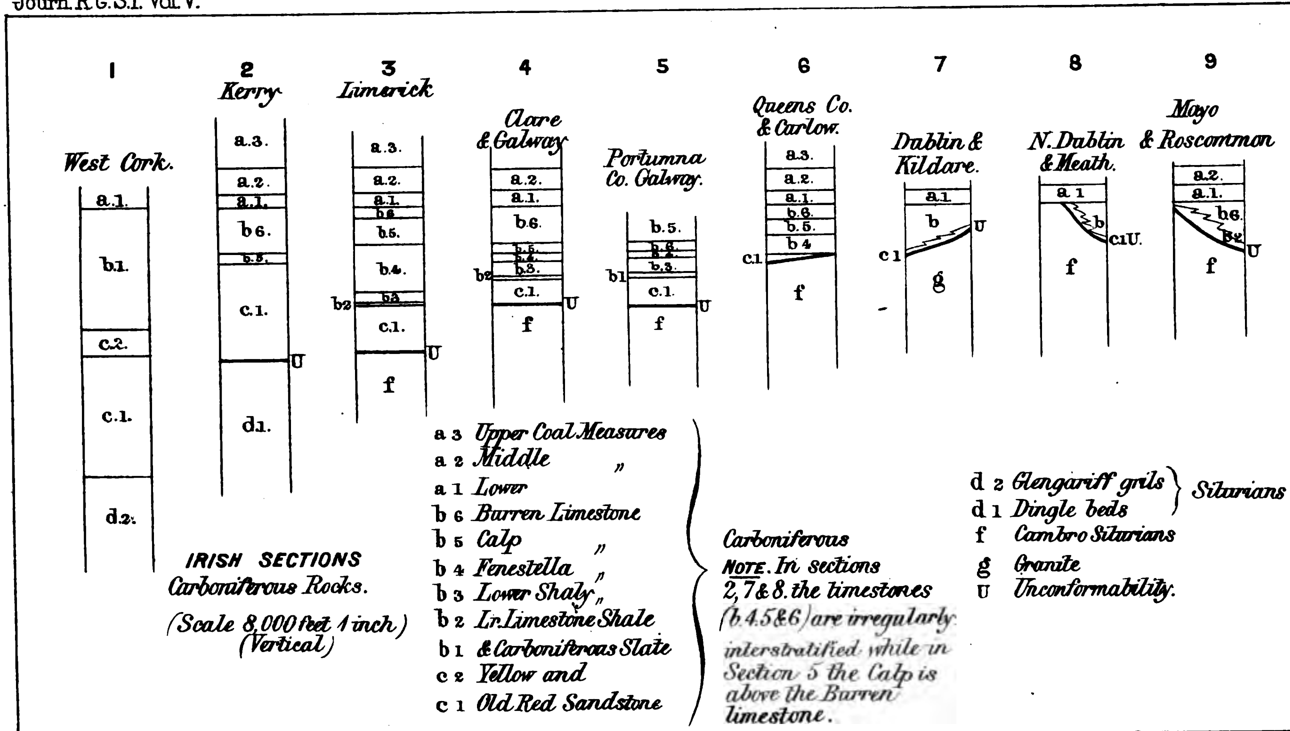

1 West Cork.
2 Kerry
3 Limerick
4 Clare & Galway
5 Portumna Co. Galway.
6 Queens Co. & Carlow.
7 Dublin & Kildare.
8 N. Dublin & Meath.
9 Mayo & Roscommon
IRISH SECTIONS
Carboniferous Rocks.
(Scale 8,000 feet 1 inch)
(Vertical)
a 3 Upper Coal Measures
a 2 Middle "
a 1 Lower "
b 6 Burren Limestone
b 5 Calp "
b 4 Fenestella "
b 3 Lower Shaly "
b 2 Lr. Limestone Shale
b 1 & Carboniferous Slate
c 2 Yellow and
c 1 Old Red Sandstone
Carboniferous
NOTE. In sections 2, 7 & 8. the limestones (b. 4.5 & 6) are irregularly interstratified while in Section 5 the Calp is above the Burren limestone.
d 2 Glengariff grits
d 1 Dingle beds
Silurians
f Cambro Silurians
g Granite
U Unconformability.

they are, indeed, lithologically somewhat similar to the Commeragh Old Red Sandstone conglomerate; but in the beds at the base of the Toormakeady conglomerate there are Silurian fossils. Silurian fossils occur also in the very similar rocks of the Mweelrea Mountains, north of Killary Harbour. These rocks are covered unconformably by the Carboniferous strata.

Section IV.—North of Mweelrea, at Clew Bay, are the Louisburgh and Clare Island beds representing in part the Dingle Beds. In these no typical Silurian fossils have been found; but lithologically they are similar, in part to the Mweelrea pebbly grits, and in part to the "Salrock Slates;" the latter being the highest group in the Galway Silurians.

Section V.—East and north-east of the head of Clew Bay are the Croaghmoyle conglomerates representing in part the Dingle Beds. No typical fossils have been found in them; but lithologically they are similar to the Toormakeady rocks and also to those in the Curlew Mountains, Cos. Sligo and Roscommon, next to be mentioned; while they are capped unconformably by the Carboniferous rocks.

Section VI.—The rocks near Ballaghaderreen and those of the Curlew Mountains are lithologically more or less similar to those already mentioned as representing the "Dingle Beds." They extend downwards conformably into Silurians which contain fossils similar to those in the Silurians which, in the Co. Kerry, underlie the "Dingle Beds;" while above, as is the case with the "Dingle Beds," they are cut off and are capped unconformably by the Carboniferous rocks.

Section VII.—The rocks of the Fintona district, Cos. Fermanagh and Tyrone, are lithologically similar to those of the Curlew Mountains, and they likewise are capped unconformably by the Carboniferous rocks. They doubtless represent the Dingle Beds. Of these Portlock states that, in one place, they seem to lie conformably on the Cambro-Silurians. Griffith, however, mentioned to me in conversation that from information he had received, he suspected that in this district, as at Toormakeady, there would eventually be found at or near the base of the Fintona rocks a bed containing Silurian fossils. This supposition rests solely upon information supplied to him, which I have not had an opportunity of verifying.

Let it be clearly understood that in no place in the above discussed rocks of Cork, Dingle, Toormakeady, Louisburgh, Croaghmoyle, Curlew Mountains, or the Fintona district, have fossils been found to prove distinctly that they are of Silurian age. The only indirect evidence of that kind which can be produced being the fossils in the Mweelrea beds, which may, perhaps, be on the same geological horizon as the unfossiliferous rocks of Toormakeady, Louisburgh, Croaghmoyle, the Curlew and the Fintona Mountains. While on the other hand it must be admitted that there are the already mentioned plants of Carboniferous type in the Dingle and Glengariff beds. Therefore it is no doubt possible, that if there really be such a distinct formation as the "Old Red Sandstone" those rocks may belong thereto. It is evident, however, that they are all of similar age;* and it is surely inconsistent that if the Dingle and Glengariff beds with their Carboniferous type plants† are classed with the Silurians, the Curlew and Fintona rocks should be put in a separate formation and classed as "Old Red Sandstone."

It would appear, then, that the lower and the upper parts of what has been spoken of as the "Old Red Sandstone" do not belong to each other as parts of the same formation, but stratigraphically are to be classed, respectively, with the strata immediately below and above them.

(2.) We now come to the second division of our argument which is that the so-called "Old Red Sandstone" beds may be sometimes older than the Carboniferous Limestone and sometimes of the same age as various beds thereof, which beds may be even at a considerable height in that formation.

In the Co. Kilkenny, to the N.E., of Thomastown, the "Old Red Sandstone" comes in as a distinct subdivision at the base of the Carboniferous Limestone and increases in thickness as it is followed to the S.W., still retaining this relative stratigraphical position.

But N. of the line joining Dublin and Galway the small exposures of so-called "Old Red Sandstone" appearing through the

* In the Glengariff Grits, the Dingle Beds, the Toormakeady Conglomerates, the Mweelrea beds, the Curlew rocks and the Fintona rocks, there are peculiar and characteristic felstones and traps that seem to be all of nearly the same age.

† As the Continental and American Geologists find plants apparently of Carboniferous types in the typical Silurians, this evidence against the Silurian age of the Dingle and Glengariff beds is, at least in part, done away with.

Limestone in the central plain and in the Cos. Galway and Mayo (except near Ballaghaderreen) graduate horizontally into limestones, sometimes of Burren or Upper Limestone type, and are in reality but shore beds formed by the Carboniferous sea, as explained in my book already referred to. Moreover in the N. part of the Co. Dublin conglomerates occur close under the base of the Coal Measures; while in the rest of Dublin, Kildare, and Carlow small patches of red conglomerate have been discovered seemingly on different geological horizons. These likewise appear to have been only "shore-beds" margining ancient lands.

And, even more than this, in the Ballycastle Coal-field, in the N.E. of Antrim, "Old Red Sandstone" (shore beds) occurs interstratified with the coal-bearing Calp.

This is also the case near Draperstown, Co. Derry, where the Calp is very similar to that of Antrim, except that no workable coal has been found therein. In Armagh the "Old Red Sandstone" is interstratified with the Burren limestone. The last three localities correspond in this respect that in the rocks associated with their Old Red Sandstone are found fish remains more or less similar among themselves, as also to the fish remains in the Burdie House limestone, Scotland. The sections in Plate 2 show the relations of the different limestones to their "Old Red Sandstones" in various places in Ireland.

We have probably now said enough to show that, certainly in Ireland at least, the title "Old Red Sandstone" should not be applied to any series of rocks, as indicative that they constitute a distinct formation. I am glad to be able to state that this conclusion is fortified by the opinion of Dr. Haughton, who so far back as the year 1863, stigmatized the Old Red Sandstone as a "phantom formation."

XI.—ON STILBITE FROM VEINS IN METAMORPHIC (GNEISS) ROCKS IN WESTERN BENGAL, BY V. BALL, M.A., F.G.S., OF THE GEOLOGICAL SURVEY OF INDIA.

[Read November 18, 1878.]

THE occurrence of stilbite in metamorphic rocks, though by no means a new discovery, is still of sufficient rarity to be worthy of record. To the best of my belief there is no published account of this mineral having been previously found in this association in India; and so far as I have been able to ascertain, it has not very often been met with under similar circumstances either in Europe or America. I may mention that during the recent meeting of the British Association several of the mineralogists to whom I showed the specimens seemed to regard the discovery as being one of interest, and without a parallel in their own personal experience.

The Cretaceous Basalts of India, otherwise known as the Dekan trap, include, in certain places, remarkably fine crystals and crystalline masses of various zeolites—including stilbite; but the mineral about to be described, though possibly of secondary, if not of intrusive origin, does not occur in contact with any demonstrably volcanic materials. It was found in the vicinity of a small coal-field*—one of a series of basins of coal measures which I surveyed in the early part of the present year. Three distinct veins of the mineral were observed. The principal one is from half an inch to ten inches wide, with a vertical underlie and strike of about 20° North of West to 20° South of East. Though for the most part the vein lies parallel to the planes of foliation of the pink porphyritic gneiss which encloses it, it does not invariably do so, as it cuts across them obliquely at several points A second vein close by, is in places one foot wide, but thins out to nothing within a short distance. A third vein of inconsiderable dimensions was also discovered. Less regularly in reference to

* The precise locality where it was found may be thus indicated. It is just inside the mouth of a stream from the Bijka peak which joins the Atee river, south of the village of Manjuri, about 16 miles S.W. of Daltonganj, in the Palamow Subdivision (*vide* Mem. Geol. Surv., India, Vol. xv., p. 37.)

the strike of the foliation of the gneiss, veins of pegmatite and epidote occur in the vicinity in some abundance.

The stilbite has a laminated somewhat hackly structure, and is of a bright salmon colour with a pearly lustre. Under the blowpipe it acts in the characteristic manner of stilbite, but it has not yet been submitted to regular chemical analysis.

Associated with it there are plates of quartz, which appear to be pseudomorphic after micaceous iron. Such pseudomorphs, together with those of barytes and gypsum, occur very commonly in India with infiltrated and occasionally brecciated matter along lines of fault and fracture. The few small specimens of these pseudomorphs which I exhibit, will serve to convey some idea of the general appearance of this fault-rock which often from its hardness, forms strongly marked ridges at the surface. The pseudomorphs after micaceous iron not unfrequently shew the very delicate superficial etching which is characteristic of that mineral. Occasionally portions of the original ore are found included in the quartz. From these facts, it seems probable that the stilbite occurs rather as a vein or lode than as a part of an intrusive dyke.

The specimens I exhibit I propose to present to the Museum of Science and Art, Dublin, and to the Museum of the University of Dublin.

XII.—ON AN ARTIFICIAL MINERAL PRODUCED IN THE MANUFACTURE OF BASIC BRICKS AT BLAENAVON, MONMOUTHSHIRE, BY J. EMERSON REYNOLDS, M.D., F.C.S., PROFESSOR OF CHEMISTRY, DUBLIN UNIVERSITY, AND V. BALL, M.A., F.G.S., OF THE GEOLOGICAL SURVEY OF INDIA.

[Read November 18, 1878.]

IN a paper read before the Iron and Steel Institute, Messrs. S. G. Thomas, F.C.S., and P. C. Gilchrist, A.R.S.M., F.C.S., have recently detailed their experiments and investigations in connection with a process invented by them for the elimination of phosphorus in the Bessemer converter. The discovery of a method by which this most important object may be attained cannot fail to have a marked influence on the manufacture of steel. The process, which has been patented in several other countries besides England, is now undergoing practical trial, and should it prove to be as successful as the inventors' experiments seem to promise, there can be little doubt that it will be possible to manufacture steel of good quality from phosphoretic pig, such as that made from the Cleveland Iron Ores, which has hitherto been rejected as unsuited to the purpose.

In the present communication it is not intended to describe this process; it will be sufficient to state merely, that the inventors have succeeded in producing a durable and refractory brick for the lining of the converters, by means of which without excessive waste of, or injury to the lining and metal, a basic condition of the slag, hitherto unattainable, has been secured. The result is that oxygen has been found not to be so "inert as regards phosphorus at the intense temperature which accompanies the Bessemer process" as had previously been supposed; but that in fact, under the conditions afforded by this new method of lining, oxygenation of the phosphorus does take place and the phosphoric oxides combining with the bases form phosphates in the slag, thus rendering it possible to draw off the steel with but an unimportant trace of phosphorus remaining.

In the preparation of these basic bricks, which are made of an aluminous magnesian limestone—an oven lined with ordinary

siliceous fire-bricks was employed, and the basic bricks were piled on the floor in direct contact with this lining. An intense white heat having been obtained, it was observed that the pile or stack of basic bricks had subsided, and on the oven being broken down after cooling, it was found that the lower layers of the pile had actually passed through the flooring, and that the siliceous bricks exhibited sharply cut moulds of the angles of the basic bricks where they had cut down through them.

The resultant fused mass occurred partly in a stalactitic form with a minutely crystalline structure, and partly as an assemblage of semi-transparent crystals.

With the permission of Mr. Gilchrist we propose to describe this adventitious result of his experiments.

The crystallized mineral occurs in long prisms, apparently belonging to the monoclinic system. Some of the crystals were nearly colourless or grayish, while others were more or less strongly tinged with green. The hardness was slightly greater than 5, and the specific gravity proved to be = 2·934.

Some of the best crystals were picked out, and afforded the following results on analysis :—

Silica,	55·35
Lime (CaO),	23·24
Magnesia (MgO),	16·20
Alumina and Ferric Oxide,	4·20
Water, loss, &c.,	1·01
	100·00

The alumina and iron are so evidently accidental constituents that their weights may be excluded from consideration in deducing the formula for this mineral. Neglecting these chance constituents then, we obtain the following formula on discussing the analytical data in the usual way :—

$$MgSiO_3 + CaSiO_3$$

Or, its formula may be written,

$$(\tfrac{1}{2}\,Mg + \tfrac{1}{2}\,Ca)\,SiO_3.$$

The mineral is therefore a Bisilicate, and is a true Pyroxene. Its composition indicates that it is a member of the group of Pyroxenes that includes Malacolite and Diopside. Messrs. Thomas and Gilchrist have therefore effected, accidentally, and under novel conditions, the synthesis of an interesting member of a most important group of minerals of natural occurrence.

XIII.—CAMBRO-SILURIAN AND SILURIAN ROCKS OF THE SOUTHERN AND THE WESTERN PARTS OF IRELAND. BY G. H. KINAHAN, M.R.I.A., &c. WITH PLATE 3.

[Read December 16, 1878.]

In this paper it is proposed to give very briefly a general view of the Cambro-Silurian and Silurian formations, and their relations to each other, as exhibited in the southward and westward parts of Ireland.

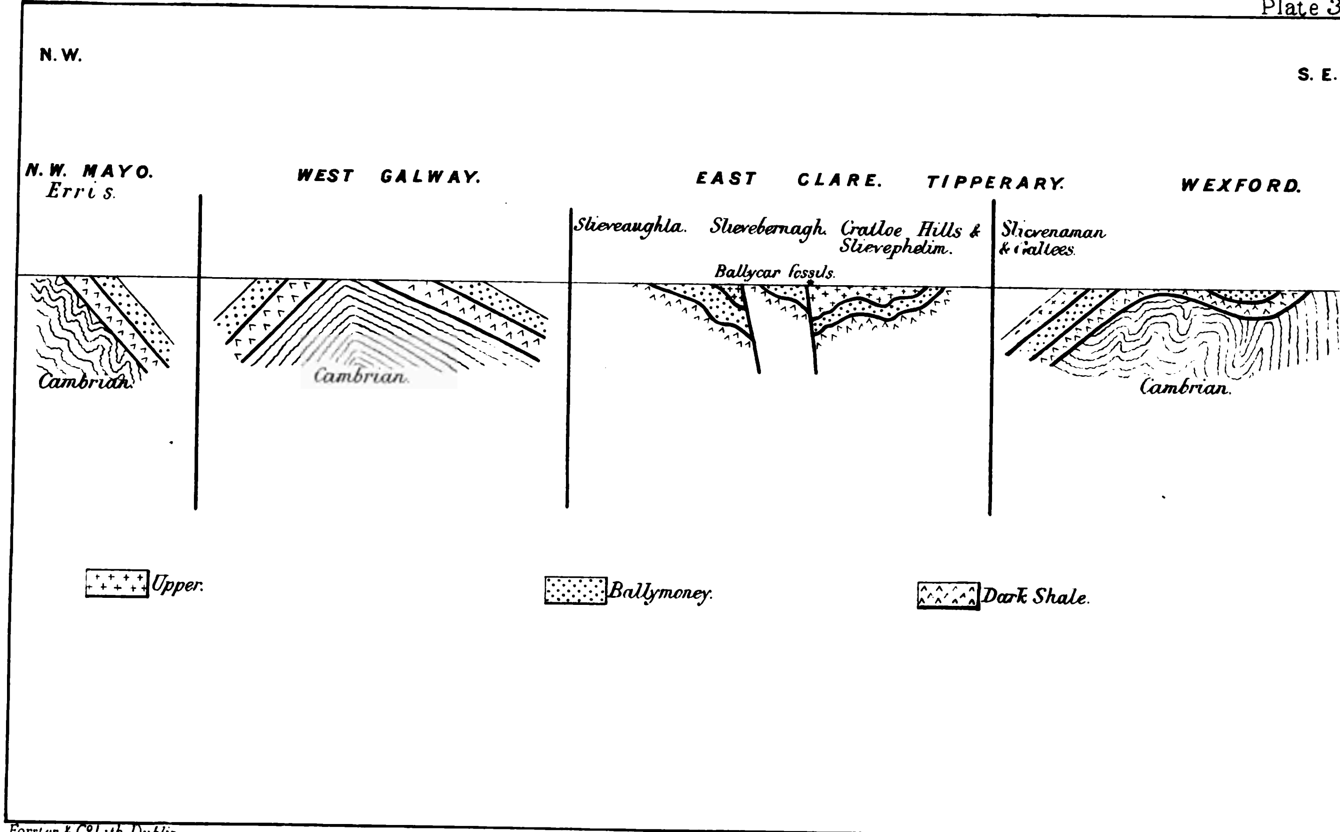
Cambro-Silurians.—In the "Manual of the Geology of Ireland," the Cambro-Silurians are separated into two divisions. This arrangement, perhaps, might be improved, by adding a third division, so as to classify the rocks as

3. *Upper Series.*
2. *Ballymoney Series.*
1. *Dark Shale Series.*

In the Slievenaman district, as also in the Galtees, there are purplish and greenish rocks somewhat like Cambrians in appearance, which Jukes regarded as possibly belonging to that formation. Until this autumn, I had not seen these rocks for a long time, some of them not for twenty-five years. I was aware that they had an aspect somewhat like Cambrians, and was inclined to suspect that they might be of that age. But last year Mr. James Budd, one of the Council of the Waterford Literary and Scientific Society, showed that the rocks at the Victoria Slate Quarries, in the vicinity of those just mentioned, in the Slievenaman district, contained Cambro-Silurian fossils; and besides this, when I was comparing, last autumn, the Cambro-Silurians of Wexford with those of Munster, it seemed to me that those purplish and greenish rocks of Slievenaman, the Galtees, and Slieve-na-muck are higher in stratigraphical order even than the rocks of the Ballymoney series.

The following appears to be a correct outline sketch of the rocks which form the subject of this paper. The Cambro-Silurians of southward and westward Ireland, lie in four about

Plate 3.



Forster & Co. Lith, Dublin.

E.N.E. and W.S.W. synclinal and anticlinal curves as indicated in the accompanying section which is only intended to represent their general position and relations.

In south-east Wexford lying unconformably on the Cambrian, are rocks of the Dark Shale series, and over the latter are rocks of the Ballymoney series. But to the N.W. in the Slievenaman district, county Tipperary, and further westward in the Galtees, county Limerick, there is also an Upper series. This is the case also in Slieve Phelim, northward of the last, and in Slieve Arra; as also in the east portion of Slieve Bernagh, and in the Cratloe Hills on the other side of the Shannon, in the last of which at Ballycar there is a colony of Silurian (Upper Llandovery) fossils —north of the last in the west portion of Slieve Bernagh the Dark Shales and Ballymoney series are represented, while still farther north in Slieve Aughta, there seems to be in addition a slight thickness of rocks belonging to the Upper series.

To the N.W. of Slieve Aughta in west Galway, and S.W. Mayo, the representatives of the Dark Shale series (Doolough beds) and Ballymoney series (Croagh Patrick beds) lie, as it would appear conformably, on an anticlinal of the Cambrian rocks. The age of the latter can scarcely be disputed; they constitute a series of strata at least 8,000 feet in thickness, which underlie the Doolough beds. The Doolough beds both lithologically and in their fossils represent the Dark Shale series, which, elsewhere in Ireland, occurs at the base of the Cambro-Silurians; they seem to be equivalents of the Llandeilos of England which are taken by Dr. Ramsay to be the base of the English Cambro-Silurians.* Farther N.W. in Erris or N.W. Mayo, similar rocks lie as it would seem unconformably on Cambrians. Between the Cambrian exposures of Erris and of West Galway, the district of Cambro-Silurians displays a great thickness of those rocks, and it is quite possible that the Upper series is there partly represented; but as all the Cambrian and Cambro-Silurian, and indeed a considerable area of Silurian, are more or less metamorphosed, it is difficult to separate the rocks into the different groups. If the suggestions in reference to Erris are correct, it is probable that in N.W. Donegal, Cambrians crop out somewhere from under the Cambro-Silurians.

It will be seen then from the above, that rocks of the Upper

* Sir Charles Lyell would make the base lower down.

series or highest part of the Cambro-Silurian may be seen in the following places, viz.: in the upland valley east of Slievenaman, in the Vale of Aherlow (Galtees), in Slieve-na-muck, in Slieve Phelim, in Slieve Arra, in the Cratloe Hills, in Slieve Bernagh, and perhaps in Slieve Aughta, and in West Mayo.

Silurians.—In a former paper, certain rocks supposed to belong to this formation are discussed; *(On the Old Red Sandstone—so called—of Ireland, ante,* page 106). The unquestionable Silurian strata in Ireland always lie with a strongly marked unconformability upon the Cambro-Silurians.

The oldest rocks of Ireland in which fossils, regarded as indicative of Silurian age, have been found, are those of Ballycar, in the Cratloe Hills, county Clare, a few miles north of the city of Limerick. But as these rocks of Ballycar appear to be in and not on the associated Cambro-Silurians, it seems to me that the Ballycar rocks are really Cambro-Silurians, and that the just mentioned fossils of Silurian type occur therein only as a colony. The probability of this is increased by the occurrence of the inverse phenomenon elsewhere, to be mentioned presently.

There are three hitherto recognised tracts of fossiliferous Silurians, namely—1st, in the Dingle promontory, county Kerry; 2nd, at the junction of Galway and Mayo; and 3rd, at Ballaghaderreen in north-east Mayo. Of these the second is the largest, it is also the one where there is the greatest thickness of strata exposed. The rocks in this area are both peculiar and interesting, but as they are fully described in the "Manual of the Geology of Ireland," I will not dwell upon them now. I must, however, mention here these two remarkable circumstances, namely, that the characteristic fossil of the highest group (Salrock slates) is considered by that eminent Palæontologist, Mr. T. Davidson, to be of Upper Llandovery type; while here, as also in the Dingle promontory is a zone carrying fossils of a Cambro-Silurian (Caradoc) type, having above and below it, especially in N.W. Galway, a considerable thickness of rocks in which are found fossils of Upper Llandovery types.

The groups of fossils indicative of the age of the English Silurians, are to some extent mixed up together in the Irish rocks; on which account they are not in Ireland a reliable test of the age of the rocks. Still it would appear that the Irish Silurians probably

range from the base of the formation upwards; as in all the lowest rocks fossils of Upper Llandovery and Caradoc types occur. I may also suggest that in Munster there cannot be a great thickness of strata absent between the Silurians and the Cambro-Silurians; because at Ballycar in the Cratloe Hills there are in the latter the above mentioned colony of Upper Llandovery (Silurian type) fossils.

I have not examined to any great extent the rocks of these two formations in Ulster, and therefore cannot add anything from my own knowledge to what has been ascertained of them by others.

XIV.—ON THE OCCURRENCE OF CRYSTALS OF SALT (CHLORIDE OF SODIUM) IN CHERT FROM THE CARBONIFEROUS LIMESTONE, BY EDWARD HULL, M.A., F.R.S., PROFESSOR OF GEOLOGY IN THE ROYAL COLLEGE OF SCIENCE FOR IRELAND; DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND.

[Read December 16, 1878.]

THE occurrence of salt crystals in the fluid cavities of granitic and plutonic rocks has been brought to light by several petrologists. Professor Zirkel has noticed them in the granite of Goatfell in Arran in Scotland;* Mr. Sorby in the quartz of the granite of Trevalgan near St. Ives,† and the Abbé Reynard in the quartziferous diorite of Quenast. ‡ Other examples might be cited. These objects are amongst the most curious and beautiful which the study of the rocks under the microscope has revealed.

During my investigations of the structure of the chert-beds of the Carboniferous Limestone of Ireland I had on several occasions noticed cubical forms, often black, but sometimes slightly translucent; these I generally supposed to be crystals of pyrites or the cavities left by them, the darkness of the sides being due partly to a coating of probably carbonaceous dust, and partly to the absorption of the light when the walls of the crystal are placed in certain directions with reference to the incident rays.

A short time since, my friend Professor A. Reynard, of Louvain when kindly sending me a thin section of the "Diorite quartzifère" of Quenast, which he and M. Chevalier de la Vallée Poussin have made the subject of special examination, accompanied this specimen by another of black chert from Ballymote, Co. Sligo, which, on examination under the microscope, I observed to contain numerous small, but beautifully perfect cubes, generally with darkened sides, but with translucent centres. I could not doubt the nature of these little cubes, after comparing them with those contained in the fluid cavities of the quartziferous diorite of Quenast, and with figures and descriptions given by Dr. Ferd. Zirkel in his valuable handbook§. My colleague, Professor O'Reilly, M.R.I.A., has been kind enough to examine the specimen, and admits the high probability that the cubical

* Zirkel. *Die mikroscopische Beschaffenheit der Mineralien*, p. 55, Leipzig (1873).

† *Ibid*, p. 57.

‡ "Mémoire sur les caractères minéralogiques des roches de la Belgique, &c.," par MM. Chevalier de la Vallée Poussin et A. Reynard, S.I., Bruxelles (1876).

§ *Die Mineralien und Gesteine*, p. 55.

forms are those of sodium chloride; he has also made drawings for me of one of the sections from Ballymote (see Fig. 1).

Fig. 1.
Chert Slice. Ballymote, Co. Sligo.
Magnifying power used, $\frac{180}{1}$ (scale approximate).

In order to observe the forms in most instances a rather high power is necessary. I find a one-inch objective with No. 2 eye-piece, magnifying 100 diameters, generally the most serviceable. With this power the crystals are distinct, but in cases where the crystals are very minute, the quarter-inch objective and No. 2 eye-piece, magnifying 350 diameters, is necessary.

The general appearance of the crystals is variable. Where the siliceous paste of the chert is clear and colourless, the crystals generally occur also colourless and slightly glistening, the edges and angles alone of the planes being apparent as fine, sharp slightly darkened lines or points, as the transmitted light is interrupted. On the other hand, where the enclosing siliceous paste is darkened, the crystals are also often darkened along the edges and angles. In many cases it seems to me probable that the actual sodium chloride crystal is absent, has, in fact, disappeared, its cavity only being left, and that the walls of the cavity are darkened by iron oxide, or by carbonaceous dust. The presence of sodium in minute quantities is indicated in some of the specimens analysed by Mr. Hardman, F.C.S., the analyses of which are given in our joint paper on the "Nature and Origin of Chert."*

* Hull and Hardman "On the Nature and Origin of Beds of Chert, &c." Scientific Transactions, Royal Dublin Society, Vol. I. (New Series), Part VII. (1877).

As I have found examples of these crystals in the chert sections taken from places in Kilkenny at the extreme S.E., and Fermanagh and Sligo on the extreme N.W., of the central plain, it may fairly be assumed that they are widely distributed wherever the chert-beds of the upper Carboniferous Limestone are to be found. Whether they may not also be found in the limestone itself is a point which as yet I have had no opportunity of determining.

I now proceed to state some of the instances referred to.

1. Co. Kilkenny, Bonnet's Rath Quarry. White laminated chert with organic structure, containing clear colourless cubes of sodium chloride in large numbers and very minute, together with some rhombic crystals of calcite. (2. Specimens from same quarry.)

3. Co. Kilkenny, Kilmagar. Dark chert with laminated structure, taken just below the Yoredale shales. Cubes with darkened sides and translucent centres. Mr. Hardman's analysis (No. XI.) indicates the presence of sodium in this rock.

4. Co. Fermanagh, Benachlan, above Florence Court. Grey chert with organic structure. Contains great numbers of very small cubical crystals, clear and colourless.

5. Co. Sligo, Ballymote. Banded chert with organic structure. Numerous clear and colourless very small cubes; others with darkened sides (see Figs. 1, 2).

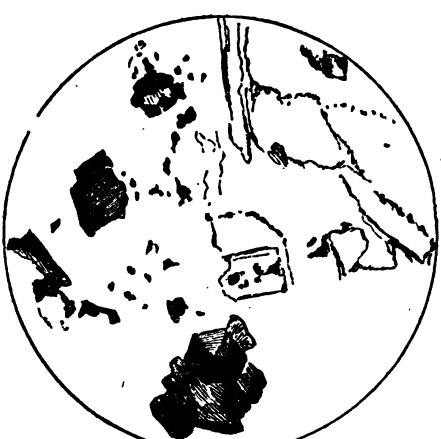


Fig. 2.
From another portion of the same section.

Mr. Hardman's analysis (No. I) indicates the presence of sodium.

6. Co. Sligo, Knock-na-Rea. Dark coralline chert containing a few large translucent cubes apparently of sodium chloride.

The figures do not sufficiently represent some of the translucent cubes described above. Crystals of calcite are also present.

XV.—GEOLOGICAL NOTES ON THE STRUCTURE OF MIDDLE AND NORTH DEVONSHIRE, MADE DURING A WALKING TOUR IN DEVONSHIRE IN THE SUMMER OF 1878, BY THE REV. DR. HAUGHTON, F.T.C.D., F.R.S.

[Read 20th January, 1879.]

DURING the course of last summer I had an opportunity of visiting in a walking tour those portions of central and northern Devonshire with which I was not previously acquainted, and I propose to bring under your notice such general results as can be obtained by a geologist on such an excursion.

It has been proposed to explain the structure of the Devonian rocks by the aid of a "fault," but, in my opinion, such an attempt is not justifiable, unless very clear evidence is obtained of the existence of a "fault." I visited Devonshire last summer for the second time, after an interval of about five and twenty years, and believe that its geological structure may be represented, without any hypothesis as to a "fault," in the following manner:—

The uppermost of the Devonian rocks form a synclinal axis half-way between Hartland, Clovelly, Bideford, Appledore, Barnstaple, and South Molton on the north, and Tintagel Head, Launceston, and Okehampton on the south; on the northern and southern edges of the synclinal beds above indicated a broad band of calcareous flinty slate and flagstone crops out, which I had an opportunity of examining at Okehampton on the south, and at Barnstaple on the north.

On the southern outcrop, near Okehampton, the calcareous slate beds overlie beds of white and yellow sandstone, and these, in their turn, lie upon the granites of Ys Tor, which is the northern edge of the granitic outburst of Dartmoor forest.

The calcareous slates west of Okehampton dip to the north-west at an angle of about 35°, but in consequence of their impurity have long since ceased to be used as a source of lime for manure, as is evidenced by the line of abandoned quarries and limekilns along their outcrop.

On the northern edge of the synclinal beds south of Barnstaple I found the same calcareous flinty slate beds as at Okehampton, dipping due south, and believe I am justified in regarding the whole of the Devonshire rocks between Barnstaple and Okehampton as forming an east and west synclinal basin.

The rocks in many places on the northern part of this synclinal show signs of violent horizontal pressure along the north Devonshire cliffs, more particularly near Hartland Point, E. of Hartland Point and W. of "Gallantry Bower," Clovelly Point, and further east near Clovelly.

To the north of Barnstaple are found the celebrated beds of *Cucullæa* sandstone, and the sandstones containing plant remains, of Baggy Point and Marwood; which are now generally regarded as Lower Carboniferous, and comparable with similar beds well developed in the south of Ireland.*

Still further to the north occurs the well-known band of marine limestone, passing from Ilfracombe, through Berry Narbor, and running east towards Exmoor forest.

This band of limestone, as well as the superincumbent slate rocks to the westward at Bull and Morte Points, dips to the south. To the N. of this calcareous band, at Lynmouth and Lynton, the rocks consist of horizontal flaggy sandstones, forming the summit of an anticlinal axis half-way between Ilfracombe and Minehead, in Somersetshire. These sandstones are the lowest and oldest rocks in north Devonshire.

At Minehead the rocks are formed of highly contorted strata, of red sandstone at the base, covered by thick beds of yellow sandstone, with a general dip to the E. of N.

The following is a rough estimate of the thicknesses of the several parts of the Devonian rocks :—

Devonian Proper.

1°. From the lowest beds at Lynmouth, occupying the summit of the great anticlinal (flaggy horizontal beds) to the Ilfracombe marine limestones, 4,400 feet.

2°. From the Ilfracombe limestones to the *Cucullæa* and plant beds of Baggy Point and Marwood, 5,200 feet.

Carboniferous Proper.

3°. From the *Cucullæa* and plant beds to the flinty calcareous slates of Barnstaple, 2,200 feet.

4°. The synclinal trough lying between the flinty Barnstaple beds and the impure limestone beds of Okehampton, 4,600 feet.

* This view was put forward by me in a paper read before the Geological Society of Dublin in January, 1855. Journal, Geol. Soc. Dublin, Vol. VI., pp. 227-241).

XVI.—ON HY BRASIL, A TRADITIONAL ISLAND OFF THE WEST COAST OF IRELAND, PLOTTED IN A MS. MAP WRITTEN BY LE SIEUR TASSIN, GEOGRAPHER ROYAL TO LOUIS XIII., BY W. FRAZER, F.R.C.S.I., WITH PLATE 4.

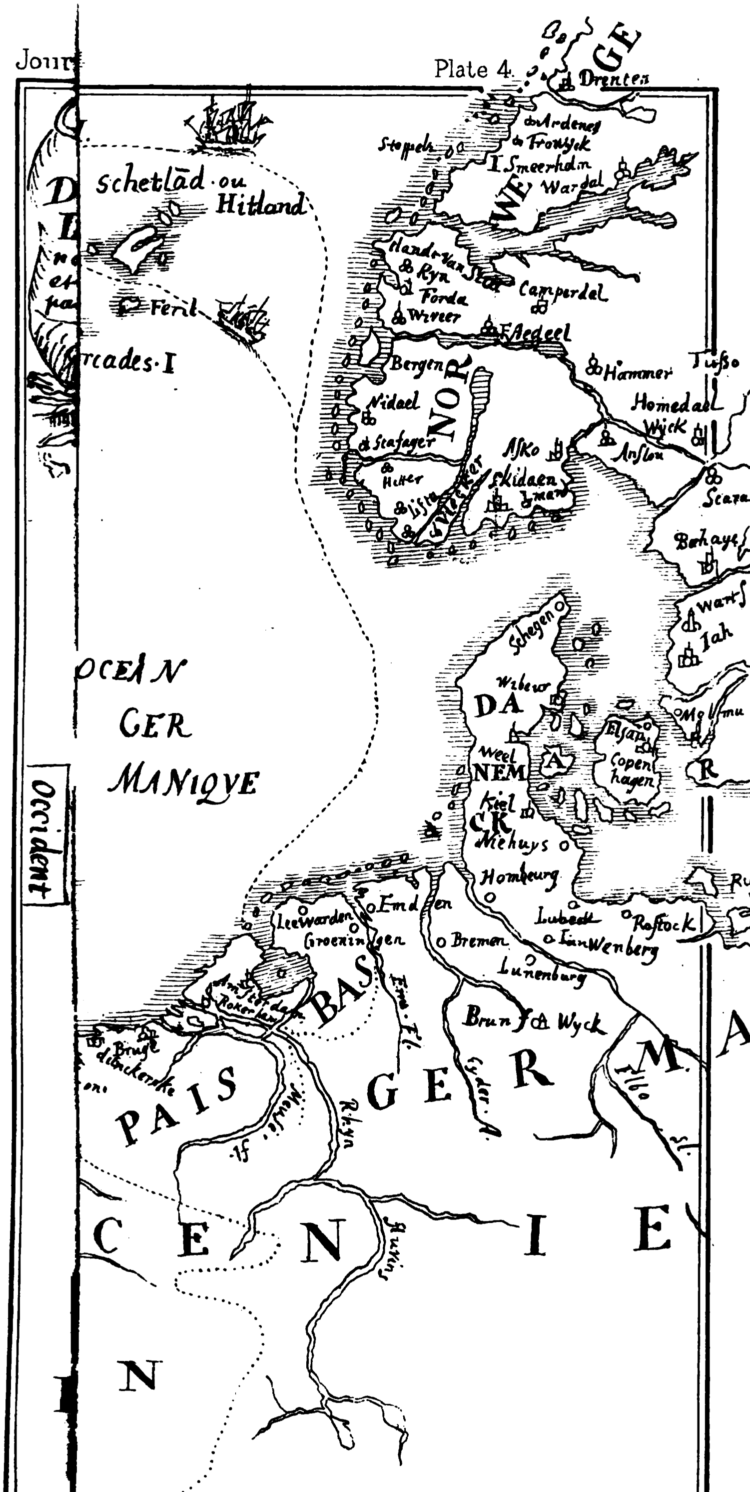
[Read January 20, 1879.]

THE French maps of the Geographer Royal, Le Sieur Tassin, in which he gives the different districts and fortified towns of France, with interesting views of the towns themselves, were published in 1634; they were re-issued more than once, the last time being in 1652. The copy which I obtained was made additionally interesting by its containing beautiful plans, drawn by Tassin himself, of several royal fortresses, which were strengthened by Cardinal Richelieu, and also bird's-eye views of Cazal and Evreux.

In the commencement of the volume laid down to scale is a MS. map of the opposite coasts of France and Britain, which I believe to be of scrupulous accuracy, even in rather minute details, and evidently the work of a man who knew the coast thoroughly. Following this is the special map I wish to direct attention to at present. It is entitled a "Chart of the Islands and Maritime Coasts of Europe, in which we see the Route and Navigation of the Hollanders by the North of Ireland and Scotland during the wars with the English by the German Ocean."

This course is laid down from Holland along the Norwegian coasts, whence two diverging paths are described—one round the north of Shetland, or "Hitland," and carried to the south of the Ferro Islands; the other, a fair-weather course, passes between Fair Island and Fula or Foula, joins the other line, and then passes inside of Rockall, or, as it is written, Rookol; it then continues along the western coast of Ireland, and Brasil is laid down in its proper place, much in the position now ascertained to be occupied by the "Porcupine Bank;" hence the course continues direct to Rochelle.

The map is evidently not designed as a fanciful sketch. Every sailing point and headland has been laid down by a skilful Geographer, who either passed over the track himself, or compiled it


Drenten
Ardenes
Frouyck
Steppels
I. Smeerholm
Wardal
Schetlād ou Hitland
Feril
rcades I
Camperdel
Ryn
Forda
Wirveer
Bergen
Hammer
Tusso
Nidael
NOR
Homedael
Wyck
Stafager
Asko
Anslou
Skidaen
Scara
Schegen
DA
NEM
CK
Weel
Elsan
Copen hagen
Kiel
Mehuys
Homburg
Rugen
OCEAN GER MANIQUE
Occident
Leewarden
Emden
Lubeck
Rostock
Groeningen
Bremen
Lunenburg
BAS
Amsterdam
Roterdam
Brunswyck
Brugge
dünckerske
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from the observations of persons who knew it thoroughly, and this at a time when no British ship appears to have sailed these western seas, though Dutch and French sailors must have made it a daily thoroughfare for their commerce.

Let me call attention to another curious matter. Rockall is represented in this map as consisting of two adjacent islands—a larger and smaller one. Well, in the cruise of H.M.S. *Porcupine* two similar banks are represented, one of large size, as occupying the place where now only one comparatively small rock remains above the waters.

In Surgeon Alex. Fisher's History of the Voyage of the *Hecla* and *Griper* in 1821, we have a description of Rockall and of a search made, of course unsuccessfully, for another phantom land "The Sunken Land of Busse." "Monday, 24th.—We had a distant view of that remarkable insulated rock, called Rockall. It looked at the distance we were from it (between four and five leagues) exactly like a ship under sail; it was reported indeed by the person who first saw it to be a strange vessel. If we estimated our distance from it at all correctly, its situation, as determined by H. M. Ship, *Endymion*, is very accurately laid down (lat. 57° 39′ 30″ N., and long. 13° 13′ W.) In the course of the afternoon, when at least forty miles from this rock, we found soundings in 150 fathoms water, so that it may be regarded as the summit of a very extensive submarine mountain, whose sides, at least the western one, declined very gradually. Thursday, 27th.—Tried for soundings on the supposed sunken land of Busse, according to its situation by Lieutenant Pickersgill, who, in his passage to Davis' Strait, in 1776, struck soundings with a line of 320 fathoms in this very place, 57° N., 24° 24′ W.; but with 1,220 fathoms of line out we found no bottom."

In the year 1576 this land of "Busse" is described as having been met by one of Frobisher's ships. It was a long island covered with wood, in lat. 57° 30′, along which they sailed for three days. So far as I can discover this "Busse" was the ship *Emmanuel* of Bridgewater; but it is needless to follow the subject further.

At numerous places round our Irish coasts, in particular along the south and west, there occur submerged bogs bordering along the coast-line, which form a conspicuous feature of our geologic

record; these every where yield remains of large forest trees that appear to have grown and decayed in the localities they are found in, and point to a time that cannot have been very remote when the land now sunken must have risen well above the water level.

There is also the traditional story told in O'Flaherty's "Ogygia," published in 1685. He says—"Lough Lurgan is an inlet of the sea, between Tuam and West Connaught, at the mouth of Galway, stretching into the land, which was formerly dry land, until the Western Ocean broke over it. The remains of the barrier are the three Isles of Aran." This traditional name of Lough Lurgan is still used for Galway Bay; and margining the Bay itself below low water mark of spring tides there are numerous bogs with oak corkers *in situ* at their base, being in places over twelve feet deep.

Nor is this the only evidence of recent subsidence, for in Mr. Kinahan's "Geology of Ireland" he records the fact that the Rev. W. Kilbride, Vicar of Aran, has discovered at Tramore, on the largest of these islands, even human habitations and other structures that he has traced down below low water of spring tides.

The legends of a buried Atlantis, larger than Lybia and Asia, described in Plato's "Timæus," of course, is one of the earliest records of this land subsidence. So universal was this belief that the first discoverers of Brazil fancied they had discovered the long-lost continent, and named it accordingly after the vanished land. It is with the last traces of such a subsidence I wish to deal. What I venture to lay before the Geological Society in support of the idea that this little island off our western coast did really exist at no very distant period, is a map in which it is drawn in its proper alleged position, made about the year 1640; that this map is the heretofore unpublished and unknown work of a competent man, a Geographer Royal of France, and in his own handwriting; that it occurs in a volume distinguished by the accuracy of its delineations, and which, so far as I can discover, is conspicuous for its freedom from errors.

This last summer I saw the cliffs of the Isle of Wight; they were disappearing at a rate of upwards of a yard each year, under the comparatively quiet waves of the ocean. Close to Bray, during last winter's storms, no inconsiderable portion of shore was removed; and if, in addition to the strong breakers of the Atlantic, we con-

sider that a process of subsidence has been taking place, submerging not only bogs, but the work of man's hands, as on the Aran Isles, surely it might happen that far less than 250 years of ceaseless surge is capable of removing more clay and rock than this little speck upon the waters must have had. It is hopeless to look for information to English sources; the navigators of their ships appear never to have sailed our western waters, and their maps, so far as I can ascertain, are unreliable; indeed, you may look in the present day over numerous English maps and fail to discover Rockall itself. So far as their evidence goes it would be conclusive that there was no such place in existence.

TITLE OF MAP. PLATE 4.

Carte de Des Isles et Costes maritimes de L'EVROPE, où lon voist La Routte et navigation des hollandois au nord d'irlande et d'escosse durant La querelle des anglois par L'ocean germanique.

XVII.—ANNIVERSARY ADDRESS TO THE ROYAL GEOLOGICAL SOCIETY OF IRELAND, BY REV. MAXWELL H. CLOSE, M.A., PRESIDENT.

[Read February 17th, 1879.]

GENTLEMEN,—At this, our anniversary meeting, we naturally look back at some of the more interesting events in connexion with our Society which have occurred during the past year. It very seldom happens that we have to record the removal from us by death, within a single year, of so many distinguished Fellows of the Society. We shall not now follow chronological order in our notices of them.

Thomas Oldham, LL.D., F.R.S., Superintendent of the Geological Survey of India, was born in 1816; he died July 17, 1878. Having graduated in the University of Dublin in 1836, he went to Edinburgh to study civil engineering; he there learned geology and mineralogy under Professor Jameson. In 1839 he became Chief Assistant to Captain Portlock, Director of the Geological Department of the Ordnance Survey of Ireland, with whom he worked in the geological examination of Derry, with parts of Tyrone and Antrim, and in the drawing up of the Report on that district, which was published in 1843. He was already a member of our Society, and in 1843 was appointed Curator of its Museum. The Council, in one of its reports, speaks of the ability, zeal, and industry of the Curator in words which seem almost like an echo of the similar testimony of Portlock to the qualities of his Chief Assistant. Oldham became, in 1844, Assistant to the Professor of Engineering in the University of Dublin, Sir John MacNeill; and in 1845, Professor of Geology in the University. In 1846 he was appointed Local Director for Ireland of the Geological Survey of the United Kingdom. It was under his directorship that the Cambrian rocks, on the east of Ireland, were ascertained to be such. The Cambrian fossil, *Oldhamia*, first found by him at Bray Head, was so named after him by Edward Forbes. He was admitted a F.R.S. in June, 1848. During the time that he was President of our Society, viz., from 1848 to 1850,

inclusive, he gave three very elaborate and valuable anniversary addresses on the progress of geological science. Our Journal contains besides several other contributions of his. Towards the end of 1850 he was appointed Superintendent of the Geological Survey of India, which post he held until the early part of 1876. The important work accomplished by that survey under his superintendence is too wide a subject for us to give even a sketch of on the present occasion. Oldham was wisely averse to the direct correlation with each other of Indian and European formations which are admitted to be comparable homotaxially. In 1875 he received from the Royal Society a "Royal Medal" "for his long and important services in the science of geology." His death took place at Rugby, where he had lived since his return from India.

Robert Harkness, Professor of Geology in Queen's College, Cork, was born in 1816, and died Oct. 4, 1878. He was a native of Cumberland. He obtained the Professorship in Cork in 1853, and in the same year joined this Society. He came to this country with an already made reputation as a geologist, having begun to write ten years before, and having contributed various papers to the Journal of the Geological Society of London, the Reports of the British Association, &c. He was admitted a F.R.S. in June, 1856. During his sojourn in this country he wrote several papers on various subjects of Irish geology. He it was who first pointed out the connexion between the metamorphic rocks of Donegal and those of the west of Scotland. Latterly he had investigated a good deal the geology of his native Lake District. On account of ill-health he had resigned his professorship shortly before his death, which event deprived our Society of one of its Vice-Presidents.

Walter L. Willson died March 27, 1878. He joined the Irish Geological Survey in 1845, and our Society in the following year. Our Journal contains some papers contributed by him. His survey work lay in the south-eastern and southern parts of the country. He was engaged on the first map (that of Wicklow) issued by the Irish Geological Survey after it had become a distinct department from the Ordnance Survey. This map is dated July 26, 1848. After remaining on the Irish Survey for twelve years, Willson, in the early part of 1857, joined the Indian Geological Survey, in

which he remained until his death, which took place in Calcutta at the date above mentioned.

We now come to a name which we have reserved to the last just because it is with us the reverse of least, the name of one whose birth and whose death both occurred in Dublin, those events being separated by the long interval of ninety-four years, whose residence, since he was old enough to have one of his own, was in Dublin, and whose wonderful and long extended geological labours were entirely directed to the elucidation of the geology of this country, and who was the constructor of the remarkable first geological map of Ireland, Sir Richard John Griffith, Bart., LL.D. He was removed from us on September 22, 1878, after having just entered upon his 95th year.

At the mention of Sir Richard Griffith, we perceive that the connexion between the Geological and the Royal Dublin Societies does not depend merely upon the arbitrary "association" that was effected a little more than a year ago. We feel on the present occasion that there is a further bond of union between the two. In the first place, they are equally concerned to join together in the commemoration of one and the same individual who was an eminent member of both Societies. For many years, in the earlier part of his long connexion with the Royal Dublin Society, he was a most active, useful, and prominent officer of that Society, and for the last ten years he was a Vice-President of the same. On the other hand, he was an original member of the Geological Society of Dublin, and at the formal opening of the Society in February, 1833, he was Vice-President thereof and afterwards President twice. At the time of his death he was still Vice-President. But, further, his long continued labours in connexion with the Royal Dublin Society, which added so much to the usefulness and prestige thereof, were all in the region of geology and mining surveying, the very province of the Geological Society; so that the two Societies are equally interested not only in the man personally, but also in his scientific work. He was the oldest surviving member of the Royal Dublin Society, having joined it in 1808, the same year in which he joined the Royal Society of Edinburgh and the Geological Society of London. If he could not be called the oldest member of the Geological Society of Dublin, it is because it was not organized until the beginning of

1833, so that several original members still survive; but he was the Nestor of Irish geology. We have spoken of our common purpose on the present occasion; it is not to join together in a lament, in an elegiac celebration of him who belonged to us both; that were surely most inappropriate. How dare we repine at the removal of him who was spared to us for a quarter of a century beyond the proverbial three score years and ten? In his 95th year he was moving among the third generation of his contemporaries

> *Τῷ δ' ἤδη δύω μὲν γενεαὶ μερόπων ἀνθρώπων*
> *'Εφθίαθ', ὅι δι πρόσθεν ἅμα τράφεν ἠδ' ἐγένοντο*
> *'Ηριν ἐν ἠγαθέῃ, μετὰ δὲ τριτάτοισιν ἄνασσεν·*

Yes *ἄνασσεν*, for his career was assuredly one of masterful activity and triumphant accomplishment.

We cannot now go into the general history of his long life and important labours; this can be found elsewhere; we shall confine ourselves to a sketch of his geological work, and this will best be made in connexion with the history of his Geological Map of Ireland.

This is a subject not only interesting in itself to us as Irish geologists, but it is profitable in various ways. It must always be instructive to know something of the progress of the work of such a man, and of his own corrections and improvements of his work. Moreover, it is good to be reminded that our present knowledge of the general geological structure of our island is by no means intuitive. When it is laid out before us on a map so that we can take it in almost at a glance, and it has become so familiar that we can hardly imagine it otherwise, we are apt to forget the toil that has been undergone, and the difficulties and obscurities that have been encountered by those who have prepared the way for us. It is good to bear in mind that only last September one was still with us who was the first geologist who ever explored certain districts of our island. It is salutary to be reminded that the Muse of geology (like, indeed, all her sisters of the natural and physical sciences) is, notwithstanding her great progress and acquirements, still only an "*ὀψίμαθης*," one who has but lately come to her learning, and that it behoves her to take heed that she be not as "*insolens*" as persons in her condition are sometimes tempted to be.

Griffith turned his attention to geology and mining engineering in the year 1800, or immediately after. Having studied chemistry, mineralogy, and geology in London for two years, under the well-known William Nicholson, and having become acquainted with practical mining in various parts of England and of Scotland, and having studied in Edinburgh under Sir James Hall, Playfair, Jameson, &c., he returned to Ireland in 1808, and immediately joined the Dublin Society. It was in the very next year that he undertook the first of his numerous surveys and investigations for that Society; this was a Geological and Mineralogical Survey of the county Dublin. In the same year he was appointed by the Commissioners as one of the engineers to examine and report on the bogs of Ireland; this gave opportunity for examining geologically various parts of the country. In 1812 he was appointed Professor of Geology and Mining Engineer to the Royal Dublin Society. It was in this year, perhaps even in the preceding, that he commenced his map at the suggestion of his friend, G. B. Greenough, afterwards the well-known author of the early Geological Map of England. About this time he surveyed the Leinster coal district, his Geological and Mining Report on which was published in 1814. In that year he made for the Dublin Society a general mining survey through Leitrim, Roscommon, Galway, Clare, Kerry, Limerick, and Cork, the length of the tour being nearly 1,000 miles; the results were afterwards detailed in his mining lectures in connexion with the Society. In consequence of the information he had already collected, combined with what little there was to be obtained from other sources, he was enabled to present in public, at his lectures in 1815, what we shall call the first edition of his Geological Map of Ireland. This was never printed. It is a curious coincidence that it was in this same year, 1815, that the first Geological Map of England, by William Smith, was *published*. His continued employment in carrying out similar works for the Society enabled him to be always adding to and improving the details of his map, until 1822, when his appointment as Engineer of Public Works in Cork, Kerry, and Limerick, gave him further facilities for obtaining information. Then in 1825 he was appointed by the Lord Lieutenant (Marquis of Wellesley) to carry out the Boundary Survey, the duties of which involved his visiting, sometimes more than once, nearly every

parish in Ireland. He still continued his work in connexion with the Dublin Society. He writes, in 1826, that he had never lost sight of his intention to make a perfect Geological Map of Ireland, and that he never misses an opportunity of making accurate geological observations. By the year 1828 he had made extensive additional surveys, and had presented numerous additional geological and mining reports to the Royal Dublin Society, so that he could then say, "There is no part of Ireland in the geological examination of which I have not made considerable progress," and he hopes at no distant period to complete his map. It is desirable to mention this here to show that his map in its inception, and the earlier part of its progress, was quite unconnected with the Valuation Survey, which we have now to mention, although it afterwards proved so useful in connexion with that Survey. Its purpose was, in the first place, scientific; the practical objects which it might subserve would, of course, not be despised, but they were regarded as of secondary rank.

In 1829 he was appointed Commissioner of the Valuation Survey of Ireland, the Bill for which had been passed three years before. He eagerly embraced the great opportunities afforded by this work for the completion of his map. What made the last two appointments so specially to be prized was the fact, not only that they involved his visiting every part of Ireland, but, also, that as the surveys were quite distinct, and their objects quite unconnected, and as they together extended over more than a quarter of a century, his repeated visits to different districts would occur at times separated by considerable intervals. Thus he had means of verifying or correcting former observations or conclusions, not only in the light of his own increased knowledge of the general facts, but also in that of progressing geological science. He himself tells us that for the improvement and completion of his map he found it necessary to revisit every district and nearly every parish in Ireland at least three times; and he tells us elsewhere that much exertion was used by him to keep pace with modern discoveries and views. Seldom has there been such a remarkable concurrence of a recognised want, the eminently suitable agent for supplying that want, and so ample opportunity for the effectual working of that agent. He was now obliged to resign his office of Professor of Geology and Mining Engineer to

the Royal Dublin Society, which he had held for just twenty years.

Though he was still continually adding to his store of facts, yet no material changes were made in his map until the early part of 1835, at which date we enter upon the second period in the history of the map. It is interesting to note this point, because it shows his prudence in contenting himself during the first period with a copious induction of facts before doing anything but what was sufficiently obvious at once as to the correlation, discussion, and interpretation of those facts. The second period in the history of the map was one of rapid change, improvement, and scientific development. Probably the reason why the second edition of the map was constructed at this time was that it might be ready for the meeting of the British Association in Dublin in August, 1835 ; at any rate, it was then exhibited to the Association, of the Geological Section of which Griffith was President.

In drawing up this map of 1835 he was assisted by the publications of Weaver, Conybeare, Buckland, Berger, Nimmo, Bald, Bryce, &c. But, except some detached hills of quartz-rock, whose outlines were adopted from Weaver, and the small granite exposure of Cavan, whose limits were taken from Lieut. Stothard, the boundary lines on his map were the result of the observations of himself or of persons acting under his direction. The most important of these observations by the officers acting under him were those of Mr. John Kelly (at his death one of our Vice-Presidents) in different parts of Ireland, of Mr. Samuel Nicholson in the north part of Antrim, and of Mr. Patrick Knight in Mayo. The only printed representation of this map of 1835 is that in John Phillips' "Index Geological Map of the British Islands," edition of 1838 (but undated). The geology of Ireland in that map is taken " by permission " from " Griffith's large unpublished map " (but see *Note, infra*). It is on the small scale of one inch to twenty-five miles, and doubtless many minor details are omitted.

In the map of 1835 the leading outlines of the formations are given with considerable accuracy; though in some cases the formations themselves were to be afterwards changed or left doubtful. We shall now refer only to the following particulars, which, for various reasons, are the most interesting. We find the Dingle Promontory and the whole of the country south of the line joining

Dingle and Dungarvan Bays marked as Transition. A great change was afterwards made in this. The Knockmealdown and Commeragh Mountains in Tipperary and Waterford are O. R. S. These were soon to be altered to Transition, and afterwards back again to O. R. S. What we name below the Fintona district, extending from Lough Erne to Pomeroy, is marked O. R. S., and so remains to the last, though Griffith doubted the propriety of this afterwards. Griffith mentions in February, 1836, that one desideratum in that map is a subdivision of the Transition, or Greywacke, slates, which the Welsh ones had received from Murchison. No rocks decidedly belonging to the Silurian system had been observed by himself, or described by others, as occurring in Ireland. Another desideratum, he says, is some division of the Conglomerate and Old Red Sandstone. It will be necessary to distinguish between the Old Red Sandstone and the sandstone connected with the lowest part of the Carboniferous Limestone. Another desideratum, he says, is a subdivision of the Carboniferous Limestone. On that map there were only two colours for the whole Carboniferous system: blue for the Limestone and the connected rocks, and black for the Coal formation.* At that time he supposed that the Calp of Kirwan was *lowest* in the Limestone division. In his paper to the British Association he speaks of the coal fields, and mentions that bituminous coal is confined to the north; he speaks of the New Red Sandstone and the Lias, &c., of the N.E. He mentions that the Wexford marls contain shells to be compared with those of the Crag. He speaks also of the Eskers. This map was ordered by Government to be reconstructed and engraved under the Board of Ordnance. This was not completed until 1838.

In 1837 the map was exhibited to the British Association at Liverpool. The Yellow Sandstone was now separated from the Old Red, and put at the base of the Carboniferous system, and his triple division of the Carboniferous Limestone into Lower, Middle or Calp, and Upper, was now first published.

In 1838 was published for the Railway Commissioners, of whom he was himself one, his "Outline of the Geology of Ireland," with his map on the reduced scale of one inch to ten miles, the date on

* We here perceive that Phillips' small map above mentioned contains one of Griffith's improvements on his map of 1835. The Millstone Grit of Leitrim and Fermanagh is indicated, as in Griffith's small map of 1838.

which is April 28. The value to the Commissioners of the information thus supplied to them is obvious.

Small details are omitted in this map. The leading boundary lines are already nearly the same as now. The Primary rocks are the mica slate, &c., of Donegal, the Ox Mountains, West Mayo and Achill, Croagh Patrick, and the stretch of country reaching from Lough Corrib to the north side of Clifden. The Transition division is Cambrian and Silurian; that of Wicklow, which is Older Transition, includes both. This, however, is still only conjecture. The Greywacke Slates, as he calls them, of South Cork are Older Transition. This erratum was to be almost immediately afterwards corrected. Indeed he had already made what we may call a step towards the truth, for the limestone of the Lee, Bride, Blackwater, &c., valleys, which was supposed to be interstratified with the slates, and to be therefore Transition limestone, he declares to be Carboniferous, notwithstanding its questionable position. What we now call the Dingle Beds and Glengariff Grits are Newer Transition—that is to say, he had already assigned them the position which further investigation more strongly convinced him was the right one for these somewhat obscure rocks. But the Transition colour still extended over what he very soon found to be the Old Red Sandstone area of Middle and East Cork, the Galtee Mountains, Waterford, and Kilkenny. He had made, however, a step in the right direction by colouring this as Newer Transition, whereas before it was simply Transition. But, on the other hand, he now carried the Newer Transition colour over the Commeragh and Knockmealdown Mountains; a step in the wrong direction, which was, however, to be almost immediately retraced. The Secondary division extends from the Old Red Sandstone to the Chalk, both inclusive. Some of his Old Red Sandstone, such as that of Slieve Bloom, the Curlew Mountains, &c., he now made Yellow Sandstone; which was with him a greater change than it would have been with others, since he was transferring the rocks in question from the Old Red to the Carboniferous.

His division of the Carboniferous System was now nearly complete. It was as follows in ascending order:—Yellow Sandstone,* Lower, Middle or Calp, and Upper Limestone, Millstone Grit, and

* Jukes agreed with Griffith that the Yellow Sandstone of the N. of Ireland formed the base of the Carb. System, but considered that that of the S. is more probably lower. Griffith, however, adhered to his opinion while aware of Jukes' doubts.

Coal Measures. But one member remained to be added; which deficiency was very soon to be filled up. His Upper Secondary is Magnesian Limestone, New Red Sandstone, Black Shale, Lias, Greensand, and Chalk. Griffith knew of the Silurian fossils that Portlock had obtained in the small slate area on the N. E. side of Pomeroy, in Tyrone; but Portlock's memoir was not yet out, and Griffith not wishing to ignore Portlock's discovery, but still afraid of being too hasty, left the small space uncoloured.

The map of which we have been speaking was dated April 28, 1838. Very shortly after that, in the same year, the large map, which had been ordered by the Government, in 1836, to be reconstructed and engraved, was brought out; though, for some reason which does not appear, it was not regularly published, so as to be accessible to all, until March 28, 1839, the date which is inscribed upon it. A copy of this was exhibited to the British Association, at Newcastle, in August, 1838, after hanging for some time in the rooms of the Geological Society of Dublin. We must guard against confusing these two maps of 1838 together; a mistake which was made by some contemporaries, and gave rise to great misunderstandings. The large map must have appeared very shortly, indeed, after the one we have just been considering; and yet it contained two very important changes, one of them apparently of a very daring character. It gave the Old Red Sandstone of Middle and East Cork, Waterford, and Kilkenny, as such, instead of what it had been supposed to be, viz., Newer Transition (Upper Silurian). And the Carboniferous Slate within the root of the Dingle Promontory and that of South Cork was now first made such, instead of what it had been supposed to be, Older Transition (Lower Silurian, or Cambrian). These changes were contrary to the opinions of Portlock, John Phillips, and other geologists, and they were strongly opposed by the admirable and veteran Weaver. They have since, however, been amply justified by the Geological Survey. We ought to mention here that in 1836 Mr. Charles W. Hamilton, sometime Secretary and afterwards President of our Society, pointed out to Griffith that the roofing slates which they together saw quarried at Ringabella, a little outside the entrance to Cork Harbour, were newer than the O. R. S. Before any fossils were discovered in the supposed Greywacke of South Cork the mistake that had been made

by all the authorities, Griffith himself included, respecting those rocks was most natural. The tremendous horizontal compression, in a nearly N. and S. direction, to which those rocks have been subjected, has produced in them a slaty cleavage which makes them resemble very much older rocks; and then the violent nearly E. and W. folds into which they have been thrown, doubtless by the same compressing force, combined with the fact that the outlines of the Carboniferous Slate areas are parallel with those folds, make it very difficult to know, without well displayed contacts, whether those South Cork rocks lie above or below those to the north of them; their stratigraphical relations, being thus rendered obscure, do not obviously correct the deceptive effect of their petrological character. The discovery of fossils in them set the matter right. The addition of the Carboniferous Slate (just above the Yellow Sandstone) completed Griffith's seven-fold division of the Carboniferous System, on which he laid much stress. In this map the small clay-slate district on the N. E. side of Pomeroy, which we have mentioned as being left blank, was now coloured as Silurian; and this was the only patch of Silurian colour on this map. But Griffith knew of the existence of Silurian fossils at Ferriter's Cove and Dunquin, near the end of the Dingle Promontory, and also at Knockmahon, on the coast of county Waterford. He believed that the base of Waterford, Cork, and Kerry is Silurian; but the country was not then sufficiently examined. He thought that the Silurian might be only an upper member of the Greywacke, rather than a distinct series. He expected that the greater part of the schistose rocks of Kerry and Cork, coloured on the map as Greywacke Slate, would prove to be Silurian, except a band of black slates in the Dingle Promontory, and running S. W. from Caherconree; these last rocks are the lowest. This last map was presented to the Geological Society of London, on May 22, with a paper, and to the Geological Society of Dublin, on June 13, also with a paper.

In June, 1840, only fifteen months after the last-mentioned edition had become accessible to the public, a new issue appeared which was exhibited to the British Association, at Manchester, in August of that year. In the short time mentioned changes had been made in the map in no less than forty places. Portrane and Lambay, county Dublin, are now made Silurian. Griffith knew

of Silurian (Caradoc) fossils at Grangegeeth, near Slane, co. Meath, and at Tramore, besides Knockmahon, co. Waterford. But as those districts had not been yet sufficiently examined for fossils he had not marked them as Silurian; he thought it unwise yet to attempt to separate them from the Greywacke. But the Dingle Beds and Glengariff Grits, with as nearly as possible their present outlines, are made Silurian, instead of mere Newer Transition. The Yellow Sandstone which had been supposed to form the chief mass of Slieve Baun, co. Roscommon, Slieve Moray, co. Galway, the Devil's Bit, and Keeper Mountains, the mountains N. and S. of the schistose range of Carn Clonhugh, co. Westmeath, &c., is now made O. R. S. Various other changes were made besides these. This map was presented to the Geological Society of Dublin, the former being withdrawn at the same time.

In August, 1843, the map was exhibited to the British Association, at Cork. It does not appear that any changes had been introduced since 1840, except that the Silurian fossil localities, already mentioned, on the coast of Waterford were marked; but in his paper accompanying the map he says that the boundary of the Silurian there must be enlarged. He had lately discovered Silurian fossils at the Chair of Kildare. In the same paper he speaks of a change which probably ought to be made, but which, in deference to the opinions of certain others, he did not make. The rocks of the district on the N. E. side of Lough Erne, the centre of which is near Fintona, those of the Curlew Mountains, at the northern end of Roscommon, and those of Croagh Moyle, &c., near the N. E. angle of Clew Bay, are apparently of similar though somewhat doubtful age. The Fintona rocks had been hitherto classed and coloured as O. R. S., but they are apparently conformable with the Silurian at Pomeroy and Lisbellaw; and the base of the Carboniferous, consisting of red and grey sandstones, lies unconformably upon the Fintona rocks. Therefore, those rocks are probably Silurian. The Curlew Mountain rocks are exactly similar to the Fintona rocks in geological position, and in composition and character [in the small map of April, 1838, these were coloured as Yellow Sandstone]. The reddish-brown sandstones and conglomerates at Newport (Croagh Moyle district) are similar to the foregoing, and are

covered unconformably by the Carboniferous Limestone at Castlebar. He seems, in the paper now referred to, to speak somewhat uncertainly of the position of the Glengariff Grits.

In 1844 Griffith read a paper to the British Association, at York, "On certain Silurian districts in Ireland." There is a tract of fossiliferous Silurians N. and S. of Killary Harbour, bounded on the N. by Croagh Patrick, on the S. by the Twelve Pins. He speaks of the fossiliferous Silurians of Waterford, Wexford, and Wicklow. These were all examined by him since August, 1843. [We find that Oldham was working out these rocks, and obtaining fossils from them simultaneously.] The large slate district of Down, Armagh, Monaghan, Cavan, and Louth is Silurian, probably all Lower Silurian, though no fossils have been obtained thence, except at its south border, at Grangegeeth, near Slane.

He had concluded, by January, 1846, that the Transition rocks of the Galtees and of Slieve-na-muck are Lower Silurian.

In August, 1853, the year of the Exhibition in Dublin, a small edition of the map on the scale of 1 inch to 16 miles was published to accompany the Instructions to the Valuators. A knowledge of the surface extent of the geological formations of the country was calculated to be of great use to the Valuation Survey; since the composition of the rocks, as a general, though not invariable, rule, affects so largely the character and value of the soil of a district. The correspondence of the boundaries of better and worse land with the geological outlines of a region is often most remarkable. A reissue of this map came out about a year afterwards which contained some slight additions. This map contained, as far as its scale would allow, all the improvements of which we have been speaking, together with some introduced by the Geological Survey, as the Cambrian areas of N. Wicklow and of S.E. Wexford.

In February, 1854, Griffith received the Wollaston Medal from the Geological Society of London, "for the valuable services rendered by him to geological science, and particularly for his Geological Map of Ireland, the result of his own labours and judicious researches." The President, Edward Forbes, in presenting the medal spoke of the map as "one of the most remarkable geological maps ever produced by a single geologist."

In 1855 a revised, and the last, edition of Griffith's large map

was engraved, by order of the Lords of the Treasury, and published. No change has been made in it since then.

In January, 1856, a copy of this map was presented to the Geological Society of France, and was demonstrated to the meeting by M. Elie de Beaumont.

In 1857 the new edition of the map was exhibited to the British Association in Dublin, and Griffith gave then a paper, and subsequently another to the Geological Society of Dublin, in which he considered certain rocks below the base of the Carboniferous system—that is to say, the Dingle Beds and Glengariff Grits, in the South, and the Croagh Moyle, Curlew Mountain, and Fintona rocks in the north, all of which he believed to be of somewhat similar age. His opinion regarding the Dingle Beds and Glengariff Grits had nearly always been substantially the same from the first; he made them Upper Silurian. As the question of the age of those rocks was under consideration by the Geological Survey he took that opportunity of bringing up the subject. He had examined those rocks again in the preceding year in company with Jukes, Murchison, and Salter. We all know that Jukes finally concluded that there was least difficulty involved in making those rocks Old Red Sandstone, and that he coloured the Glengariff Grits as such on the Survey maps, though he left the Dingle Beds provisionally with an indecisive colour. We are told that on the occasion just mentioned Murchison was inclined to side with Griffith, although Murchison and Phillips, after visiting together the Dingle Promontory in 1843, immediately after the meeting of the British Association in Cork, had concluded that those rocks were Old Red Sandstone.

Griffith, then, observes that, as he expresses it, the Glengariff Grits in the Dingle Promontory lie conformably on fossiliferous Upper Silurians, and are covered unconformably by the O. R. S. Stratigraphically, therefore, they are more closely connected with the Upper Silurian. Besides this there is the occurrence of similar felstones and ashes in the Silurians and in the Glengariff Grits of Dingle. There is, therefore, a double probability in favour of those Grits being Silurian rather than "Devonian." But the Glengariff Grits N. and S. of Dingle Bay are identical in character, and seem to belong decidedly to the same series of rocks. It is true, indeed, that on the S. side of Dingle Bay the O. R. S. lies

conformably on the Glengariff Grits, and this is unquestionably a considerable difficulty. But the difficulty is somewhat lessened by taking the Grits on the S. side as being higher in the series than those on the N. side of Dingle Bay; he only offers this for as much as it is worth. There is another difficulty, though not a serious one—viz., that the Glengariff Grits of the Dingle Promontory are derived from Silurian rocks. They can, however, very well be Silurian for all that.

Although, then, Griffith, in bringing out the later editions of his map, availed himself of the determinations of the Geological Survey when they recommended themselves to him, yet in the matter of the rocks now in question he maintained his opinion in opposition thereto. And it would appear now that the arrangement advocated by him will be introduced into future editions of the Survey maps. I understand that there is a contribution to the controversy to be presented to another Society almost immediately. As we have not this before us we shall not now go into the question.

In the papers just mentioned Griffith speaks again of the Fintona, Curlew Mountain, and Croagh Moyle rocks, characterized by brown and reddish brown grits and conglomerates. There is, he says, a sufficient similarity to justify comparison between these and the Dingle and Glengariff strata. These were, from the first, coloured by him on his map as Old Red Sandstone (except that for a short time the Curlew Mountain rocks were marked as Yellow Sandstone). However, as we have seen, by the year 1843, he saw reason for doubting this arrangement, and he now repeats the arguments for connecting those rocks with the Upper Silurian; but whilst unacquainted with the real relations of the Devonian he allows them to remain provisionally in this latter formation in deference to others, but distinguishes them in a note on his map. The Geological Survey have since taken these rocks in hand; but I do not know whether they have yet come to their final decision upon them.

To the last we find certain districts, the largest of which is in Donegal and Londonderry, marked on the map as "Primary." Doubtless this was done at first in accordance with the views of the time; and probably the title was afterwards continued for convenience, it not being intended to mean thereby more than

relatively oldest, or belonging to the oldest division. It seems to me that this name, which is a relic of archaic geology, though standing on the map with a modernized meaning, is a very interesting indication of the far back time when the map was commenced; and I for one should have regretted very much if this, the only remaining indication, had been expunged. As a provisional name, consisting for convenience of a single word, probably "Primary" is as good as any for those unquestionably ancient metamorphic, and therefore disguised, rocks. If they were simply marked as metamorphic, that would not necessarily exclude their being as late as of Oolitic age. Very likely it may never be possible to determine the age of some of those rocks. Jukes thought it probable that some of them in the N.W. might be Pre-Cambrian; it is supposed by some, as Prof. King and Mr. Kinahan, that some of those in the W. so marked are Cambrian; and the fossil evidence obtained by Prof. King only last year shows that some of the Donegal "primary" rocks are Lower Silurian. Let us hope that the investigations of the Geological Survey may result in the determination of these points.

We find in more than one place in Griffith's writings that he was projecting "an extended work explanatory of the details of his Geological Map," but that he was prevented from beginning it by his various public employments. I am informed that he did begin to write such a work after his retirement from the Valuation Survey, but that it is to be feared that it never was finished. It is earnestly to be wished that whatever writings on the subject of the Geology of Ireland he shall have left behind him may soon become accessible to us. If it be said that we surely ought to be content with his map, we reply that it is the very excellence and completeness of that map that makes us so desirous of possessing whatever else may have come from the same hand.

As we have been dwelling upon the first Geological Map of Ireland, and have incidentally mentioned that of England, it is appropriate that we should record, and it is a curious coincidence that we should have to record, the death of Alexandre Felix Gustave Achille Leymarie, which took place within a fortnight of the departure of Sir Richard Griffith. He is reported to have constructed the first geological map of France. He was Professor

of Mineralogy and Geology of the Faculty of Science in Toulouse, and died October 5, 1878, at the age of 78 years.

But now we must return to ourselves for a time. Within the last year no less than two books on the Geology of Ireland have been brought out by Fellows of this Society. I say Fellows of this Society, for though both the gentlemen referred to belong to the Geological Survey, those books are not official manifestos; they do not simply embody the official geological creed of either of their authors; they are far more interesting and valuable to us than if they did so. I mean Professor Hull's Physical Geology and Geography of Ireland, and Mr. G. H. Kinahan's Manual of the Geology of Ireland. Fortunately for us each work was undertaken, and all but completed, before it was known that the other was in hands; if it had been otherwise we might, perhaps, have had only one of the two. But though this was so, we might almost have imagined that there had been a mutual arrangement whereby the two books might not interfere. The general plan and object of each are different, and though, of course, to some extent, the same material is common to both, yet it is generally introduced in a different way, and regarded from a different point of view. So that there is ample room for both books, and neither can be spared because we have the other. It so happens that these two books correspond respectively to two similar books devoted to the geology of England. It is expressly mentioned in one of those books that I do not agree with all the positions therein taken up. If either had come out singly, perhaps I might have ventured to give some review of its contents; but if I were rash enough to criticise both, the authors would doubtless combine together at once to annihilate me. But this I can do with safety to myself, and also with cordiality and a clear conscience, viz.—congratulate the Society on the emanation from within itself of two so useful and valuable works on the geology of our island, supplying a want which had long been keenly felt, and on the removal of the stigma which the existence of that unsupplied want was calculated to cast upon us.

There are various other subjects on which we might dwell, such as the meeting of the British Association in Dublin in August last, with more special reference to the proceedings of the Geological Section of the Association; but I must not occupy your attention

for too long. I now beg to thank you for the honour you did me in putting me into this Presidential chair, and for allowing me to remain there for two years, and to ask your indulgence for any shortcomings that you may have perceived in my occupancy thereof.

XVIII.—NOTES ON THE ANCIENT AND RECENT MINING OPERATIONS IN THE EAST OVOCA DISTRICT, BY P. H. ARGALL. PLATES 5 and 6.

(Communicated by G. H. KINAHAN.)

[Read March 17th, 1879.]

Introduction.

IT is proposed to describe in this communication the mineral lodes and mines in the country east of the Ovoca river, but without giving more than a short sketch of the geology of the district.

Many years ago the geology of this area was described in a paper read by Mr. Thomas Weaver before the Geological Society of London (*Trans* vol. v., 1821). Other early writers have also written on it; while in later years it has been examined more in detail by the officers of the Geological Survey (Profs. Oldham, Smyth, and Jukes, and Messrs. Wyley, Du Noyer, and Kinahan).

From the researches of these gentlemen we learn that the rocks in which the mineral lodes occur belong to the Cambro-Silurian or Lower Silurian formation.

Formerly it was supposed that the minerals occurred in beds which were deposited contemporaneously with the existing rocks; but recent researches have shown, that although in general the direction of the lodes is more or less close to that of the strike of the rocks, yet the lodes always cross the beds, though sometimes at a very small angle; in depth the lodes always underlie at a greater angle than the rocks.

The rocks of the country are principally killas (slates and shales) which are all slightly metamorphosed; but associated with them are felspathic and pyroxenic rocks. All the pyroxenic rocks are supposed to be intrusive, some being very granitic (Granitone); There are some remarkable peculiarities connected with the felspathic rocks. Weaver, in his writings, calls some of them hornstones, others quartz rocks, while more recent writers have classed them as siliceo-felspathic rocks and felstones. They were supposed at one time to run parallel with the mineral channel; but Professor Smyth has pointed out that in some places they

cross from the south to the north side thereof; and lately I have learned from Mr. Kinahan's work that they are most irregular, occurring in isolated masses more or less surrounded by killas, they being situated in general to the south of the mineral channel, but not always; as to the East they are found northward of the main lode. Mr. Kinahan has also proved that, although some of the felspathic rocks are intrusive felstones, the majority (the hornstones and quartz rocks of Weaver) are metamorphic rocks; the felspathic tuffs, the slates and shales, in places having been altered into rocks like hornstone, felstone, and other igneous rocks.

The felspathic rocks (felstones and hornstones) are most important, as a careful mapping of them has proved the existence of great disturbances in the country older than the formation of the mineral veins; other breaks seem to have been produced contemporaneously with the vein fissures, and some are evidently newer, as has been proved by the subterranean operations.*

We may expect further details of the geology of the district when the examination of it is complete, and the new maps and report of the officers of the Survey are published.

General Description of the Mineral Lodes.

The lodes upon which mining operations have been carried on east of the Ovoca occur, as previously stated, principally in killas (slates and shales), in a length of country extending from the Ovoca river for about six miles in the direction of N. 50° E.† The lodes are not, however, continuous for this distance, as they are broken and displaced by numerous faults, and in places intervening tracts of "Dead Ground" occur, in which the regular lodes have not been found. The ground will be described beginning to the west.

Tigroney and West Cronebane.

In the Ovoca valley there is a large and very well-displayed fault, known as the *Great Flucan*, which, together with the east head in Ballygahan Mine to the west, causes a left-hand displace-

* Mr. Kinahan's work I more especially mention, as I have had the advantage of accompanying him on numerous occasions during his examinations of the districts, and am consequently more or less familiar with his conclusions.

† All bearings are magnetic, 22°5 W. of true.

ment of the lode in the Ovoca valley of 384 fms.; this flucan is best seen in the Tigroney mines, where all the principal levels have been driven on it for a considerable distance, some of them for more than 100 fms. Most of the old levels which were driven in the lode were taken down in the great fall which occurred in this mine about 15 years ago, and consequently new levels ("safety levels") had to be driven in the north ground, or foot-wall of the lode. The flucan, which principally consists of tender, decomposing clay slate and soft, white, unctuous clay, offered considerable facilities for the driving of the new levels, the surrounding country being of a very hard nature. The parts of these which have been driven in the flucan can be easily seen in the plan of Tigroney Mine on the accompanying map (Plate 5). The Deep Adit (A) is driven in from the river, until it intersects the flucan, along which it is then driven for 64 fms., from which point a cross-cut southward of 11 fms. cuts the lode. The deeper levels are driven up in a similar manner from Williams's shaft to under this point in the Deep Adit, where they turn off from the flucan, and are driven in the lode. This flucan averages two fms. wide, bears N. 28° E., and dips eastward at 70°. One hundred and twenty fms. eastward there is a reversed fault, which, in the vicinity of the Baronet's shaft, heaves the lode 13 fms. to the right hand; it underlies eastward at 45°, coming to the surface on Tigroney brow. This fault is well shown in cross section No. 3. Further eastward, at the boundary between Tigroney and Cronebane, the lode is shifted by a N. 40° E. left hand displacement of 20 fms.; from the plan it will be seen that the reversed fault lengthens the lode as much as it loses by the N. 40° E. left-hand heave.

Still further eastward the lode is cut off by the western boundary of the "Dead Ground," which underlies west at 50°. The great sulphur lode varies in width from a few inches to 11 fms., and averages about 5 fms.; it is more or less wedge-shaped, the hanging wall being more perpendicular than the foot-wall.

In West Cronebane there is, on an average, a depth of 6 fms. of drift over the lode, under this is found a ferruginous breccia (angular pieces of the country rock cemented by iron) resting on the gossan, which here is limonite, nearly all of which was taken out during the demand for iron ore a few years ago. The gossan and breccia thins out, going westward, until, eventually, on

Tigroney brow, both have been removed by denudation, and the iron pyrites (sulphur ore) comes up to the surface. The gossan in West Cronebane is found in places to rest on beds of ferruginous clay; and in one place I have found black carbonaceous clay, resembling the "coal ground" of the Magpie, at the footwall; generally, however, the gossan is found to rest upon soft steatitic slaty clay, containing strings and bunches of melaconite and fahlerz, with small leaves of iron pyrites, and occasional veins of the same in a granular state, composed entirely of small loose crystals of pyrites; but in depth this "sand ore" loses these characters and becomes compact. In depth the thin leaves of pyrites rapidly increase in number and thickness, cutting out the intervening leaves of killas, until, eventually, the entire width of the lode is filled with more or less fissile iron pyrites. Still deeper the iron pyrites becomes more compact and interlaminated with hard killas; under the latter circumstances the hardest ribs generally contain 2 per cent. of copper.

Previous writers have not drawn attention to the smooth horizontal joints ("beds" or "floors") in the lode which occur at intervals of 1 to 1·5 fms. in depth, some of them being continuous for 8 fms. in length, and always being the entire width of the lode, but in no case are they known to extend into the adjoining country. These "beds" divide the ore into tabular masses, which are crossed in places by two systems of obliquely standing joints which subdivide the mass, and occasionally form triangles. These are of great importance to the miner, as when one of these triangles is cut away a large fall of ore is obtained, especially when there are clayey partings on the walls.

At the Copse shaft the sulphur lode is cut out in depth by the westward underlie of the "Dead Ground" (cross section No. 5); but elsewhere it has not been proved to its full depth.

Seventy fms. east of Williams's shaft the lode is 8 fms. wide at surface (cross section No. 2), decreasing to 6 fms. at the 77-fm. level, below which it is suddenly cut off by a slide underlying south at 45°. This slide was sunk on for 13 fms., and a well-defined vein of cupreous sulphur ore, 2 fms. wide, found, the walls of which are opening in depth. This sulphur ore has not been proved below the 90-fm. level, which is the deepest point reached in any of the eastern Ovoca mines; this remarkable displace-

ment, shown in cross section No. 2, has been called a "splice in the lode."

Yellow Copper Ore Lodes.

The country rock for a considerable distance north and south of the main pyrites lode, in Tigroney and West Cronebane, is mineralized, containing finely disseminated particles of iron and copper pyrites, which on the surface have become oxidized, giving the decomposing rocks a burnt aspect; these rocks also bear evidence of metamorphic action. In these mineralized rocks, for a width of 25 fms. to the south of the main lode, the yellow copper ore lodes occur. As pointed out by Mr. Weaver, there are in these rocks horizontal joints ("beds or floors") apparently unlimited in extent, some of which are open fissures two inches wide, others, again, are so close you could not insert the blade of a knife between the joints; these "beds" generally occur at intervals of about 5 fms. in depth, and are crossed nearly, but not quite, at right angles by a system of almost perpendicular joints, dividing the country rocks into huge rectangular masses. None of the copper ore lodes have gossan backs, but when one of these horizontal floors occurs at or near a copper lode, its back is filled with a sort of gossan made up of small fragments of the country rock cemented by oxide of iron and stained with copper.

The yellow copper ore lodes are in general lenticular masses or cakes of ore apparently lying with the strike and dip of the "country rocks;" these cake-like masses thin out in depth and length, and in places break suddenly into strings, some of which lead to other cakes. Sometimes, however, two or more cakes may be partly in contact, thus enclosing "horses" of the country rock, which have been cut away with the ore, thus leaving in the old workings spaces up to 10 fms. wide. In connexion with these cake lodes are caunter lodes; some of these occupy lines of fault which cross the country rocks nearly at right angles; a good example of this kind can be seen in the "Grass level," where the country rocks have a general strike of E. and W., and are crossed by a fault bearing N. 20° W. This fault in the "Grass level" is the western boundary of the dead ground between East and West Cronebane, and contains a 2-feet wide vein of rich chalcopyrite with a little quartz. Oftener, however, these

caunter lodes occur in the almost perpendicular joints which traverse the country rocks; when they join into the cake-like masses they form T shaped veins, which contain copper ore of a higher per-centage than the true lodes. All these lodes afford fissile chalcopyrite associated with quartz and killas. The killas always occurs in laminæ, while the quartz often forms a sort of gangue.

Dead Ground.

The great sulphur lode in West Cronebane is cut off towards the east by the "Dead Ground," as previously stated, and is not again found profitable until East Cronebane is reached, at a distance of 300 fms. In the strike of the lode, however, in both mines, extending respectively eastward and westward, for a considerable distance after they become unprofitable, are veins of soft ground with strings of the ore; so that the actual width of ground supposed to be without the sulphur lode is about 200 fms. In this ground (Cronebane Hill), dead as regards the sulphur lode, occurs the previously mentioned "Grass level" lodes.

In the south-eastern flank of this hill, a mineral channel extends for 150 fms. west from Yellow Bottoms shaft, and in it four or five E. and W. lodes occur. *I.* To the westward is the *Raddle lode;* this is perpendicular and 2 fms. wide at surface, narrowing to 1 fm. at the old 33 or Cronebane level; near the surface, or forming a back for 15 fms. in depth, is a very arenaceous Raddle, the sandy matter predominating; below which the vein is filled with whitish felspathic clay, locally called "white ground," and occasional strings of chalcopyrite. *II. Blue Burrows lode.*—This is 2·5 fms. wide at surface, narrowing to 2 fms. at the old 33 level; it has a gossan or back of limonite extending for 5 fms. in depth, under which is found blue steatitic clay ("soft ground,") with strings of melaconite and fahlerz, and at a depth of 12 fms. iron pyrites in connexion with chalcopyrite, and sphalerite; but at the old 33-fm. level pyrites appear to predominate. This lode dips south at 70°, and has not been proved below the old 33 level, but evidently in depth it will make a sulphur ore lode. Recent explorations would go to prove that this lode and the Discovery lode, on which there are "old men's" workings, may be part of the same lode. It also seems not improbable that this lode may

represent the main sulphur channel in the supposed dead ground between East and West Cronebane. If this supposition is correct, hereabouts the main sulphur lode is heaved south; but nothing positive can be stated until the Blue Burrows lode is proved in depth. Its gossan and gossan ore are very similar to those in the Magpie Mine. *III. Discovery lode.*—This possibly is part of the Blue Burrow lode as just mentioned. *IV. Morgan's lode.*—There are "old men's" workings on this lode, but very little is known about it at present, except that it is a nearly perpendicular E. and W. vein. It is said to have been worked for copper ore before Weaver's time. *V. Yellow Bottoms lode.*—This was a massive shoot of chalcopyrite which continued in depth for 53 fms., with an average breadth of 1·5 fms., and dipped south at 70°. Six fms. west of Yellow Bottoms shaft it is crossed by a fault bearing N. 50° E., which displaces the lode its own breadth. This lode seems to die out east and west in the country rock.

The mineral channel in which these five lodes occur is separated from that of the Magpie or East Cronebane by a N. 45° W. fault, which displaces the rocks of the country to the north and south. Formerly it was supposed that the mineral channel of the Yellow Bottoms contained a sulphur lode, which was a continuation westward of the main sulphur lode of the Magpie, next to be described. Recent explorations, however, have shown that such is not the case, but that the latter lode towards the W. splits at the Quaker's shaft, and that both branches in a short distance become unprofitable, and eventually die out in the hard killas of the faulty ground; so that no connexion whatever can be traced between this lode and those in the Yellow Bottoms. The latter have E. and W. bearings, while the Magpie has a bearing of N. 60° E.

East Cronebane and Connary Mines.

East Cronebane ordinarily includes the Magpie Mine and adjoining veins, also the Yellow Bottoms lodes; the latter, however, we have found more convenient to describe in connexion with the "Dead Ground," with which they are more immediately connected.

Magpie Mine.—Here the north or main lode, as just now stated, branches going westward from the Quaker's shaft; north-

eastward it is continuous for 112 fms. (until we nearly reach the Butts shaft), where it again branches; the north branch being only 32 fms. long, and being cut out by the hard country rock; while the south branch continues eastward to the "N. 32° E. head," and along the latter into Connary.

Along the N. 32° E. head into Connary the lode averages 3 fms. wide, while from this head westward to the Magpie shaft it averages 10 fms. wide, with a bearing of N. 60° E., and dip of 60° towards the south.

At the Magpie shaft the lode continued productive for a depth of 75 fms. from the surface (cross section No. 7), below which point it is suddenly cut out at the 83-fm. level by the descent of the hanging wall, in connexion with a protrusion of felsitic granite, at the foot-wall. Seventy fms. north-eastward, at the Old Whim shaft, the lode is 13 fms. wide at the surface (cross section No. 8), narrowing to 6 fms. at the 75-fm. level, where it becomes unprofitable. At the 23-fm. level the foot-wall makes a sudden bend southward, forming a step or "warp," and narrowing the lode from 10 fms. to 5 fms. in width. The foot-wall of the main lode is more or less irregular, forming a considerable number of such "warps," and at these all the rich bunches of copper ore were found; while in the more perpendicular parts of the lode the copper ore veins were generally very thin and poor. At the Butt's shaft (cross section No. 9) the lode is 15 fms. wide at surface, which width it carries down to the 23-fm. level, where the foot-wall makes a warp, narrowing the lode to 6 fms. At this shaft the lode was found to be profitable for a depth of 65 fms. from surface.

The gossan of this lode is principally limonite with a little ochre; it occurs in bunches in ferruginous clay; these bunches of gossan are generally about 5 fms. in length, 1·5 fms. wide, and 6 fms. in depth; sometimes they are connected by a string of ochre; but in those places where they are almost in contact a small vein of limonite invariably connects them. This gossan contains some auriferous silver, which is said to have been extracted by the old men. Under the gossan there is in general 1·5 fms. of "gossan ore," principally melaconite and fahlerz with a little argentiferous galena. This "gossan ore" rests upon "soft ground" (blue steatitic clay) containing interlaminated strings

and partings of melaconite, fahlerz, iron pyrites, marcasite, argentiferous galena, and occasionally chalcopyrite, and native copper; in depth the other ores gradually give place to the sulphur ores; the copper ores are seldom found at a greater depth than 40 fms.; while the argentiferous galena generally disappears at 30 fms. from surface.

In connexion with these ores large masses of black carbonaceous killas (" coaly ground," so called from the resemblance to coal) occur, generally as the foot-wall of a copper ore seam or vein. The native copper is mostly found in the "coal ground" under the copper ores. I have found that this "coal ground" contains about 12 per cent. of graphite, and that a piece of it when in contact with a piece of metallic iron has the property of receiving a deposit of metallic copper, if both are immersed in the mine water, which is a solution of copper and iron sulphates.

At the Magpie shaft the main lode is entirely in the killas; while 20 fms. to the south of it, also in the killas, is the "south lode," which here is 10 fms. wide, and is composed of whitish felspathic clay, with a little kilmacooite and copper ore. Farther eastward, at the Old Whim shaft, a south lode similar in composition to that just mentioned has also been found. It, however, has a different position, inasmuch as the first occurs in killas, and lies 20 fms. south of the main lode, while that at the Old Whim shaft is only 6 fms. south of the main lode, and has the felstone forming ts hanging wall, thereby becoming a "contact deposit" (a lode separating rocks, geologically different). It is, however, possible that these lodes may be portions of the same lode, which was broken and displaced by a fault. Here there is a large mass of intrusive felstone which suddenly cuts of the killas to the east of the Magpie shaft.

Madam Butler's.

The Lodge level (the only south adit, and probably the first driven) cuts the main sulphur lode of the Magpie at the Old Whim shaft, at a depth of 25 fms. In it three small veins of chalcopyrite and two sulphur veins were discovered, as follows:—The first towards the south is a vein of chalcopyrite in a gangue of kilmacooite (blue stone). This vein was driven on for 4 fms. towards the west, and at the end a winze was sunk 5 fms., the

ore in depth increasing in size and quality. The second is 6 fms. farther north, and in the south shaft (Madam Butler's) it was 2 feet wide, yielding chalcopyrite in a gangue of quartz with chlorite. Five fms. still farther north is the third, or Madam Butler's vein, and in the north shaft it was 2 feet wide, yielding chalcopyrite with a gangue of kilmacooite. This vein was worked for copper by the "old men;" but on account of the kilmacooite it is doubtful if they were able to dress the ore to a profit. Two fathoms north of Madam Butler's shaft the fourth lode occurs, where it is 2 fms. wide, and composed of soft dark killas with specks and strings of iron pyrites; while 8 fms. to the north of the latter there is a second vein of soft killas containing iron pyrites and a little chalcopyrite. This vein was driven on in search of copper by the "old men," but was not found profitable.

These five lodes occur in the felspathic country rocks (ash or tuffs), while immediately north of the fifth or north lode, hornstone comes in, and a little farther north a protrusion of felstone; but about sixteen fms. westward of the Lodge level there is a fault bearing about N. 25° W., which cuts out the hornstone and felstone, and brings in the country rock. The effect of this fault on these five lodes is unknown; but probably it cuts off the previously mentioned Magpie south lode.

This felstone contains a very large per-centage of iron pyrites, while there is scarcely any in the hornstone. The latter has a similar underlie to the country rock, and southward seems to graduate into it.

The south lode of the Magpie, at the Old Whim shaft, as seen in the Lodge level, is nearly entirely filled with whitish felspathic clay. It is like decomposed felstone, and occurs in every stage from a hard stone to fine clay. As this lode is followed eastward it separates from the main lode, and at the N. 32° E. head there is a thickness of 32 fms. of killas between them. The N. 32° E. head cuts off the south lode, but the north lode, as previously mentioned, turns along it towards the N.E. for about 100 fms., when it again turns and takes its normal bearing, N. 60° E.

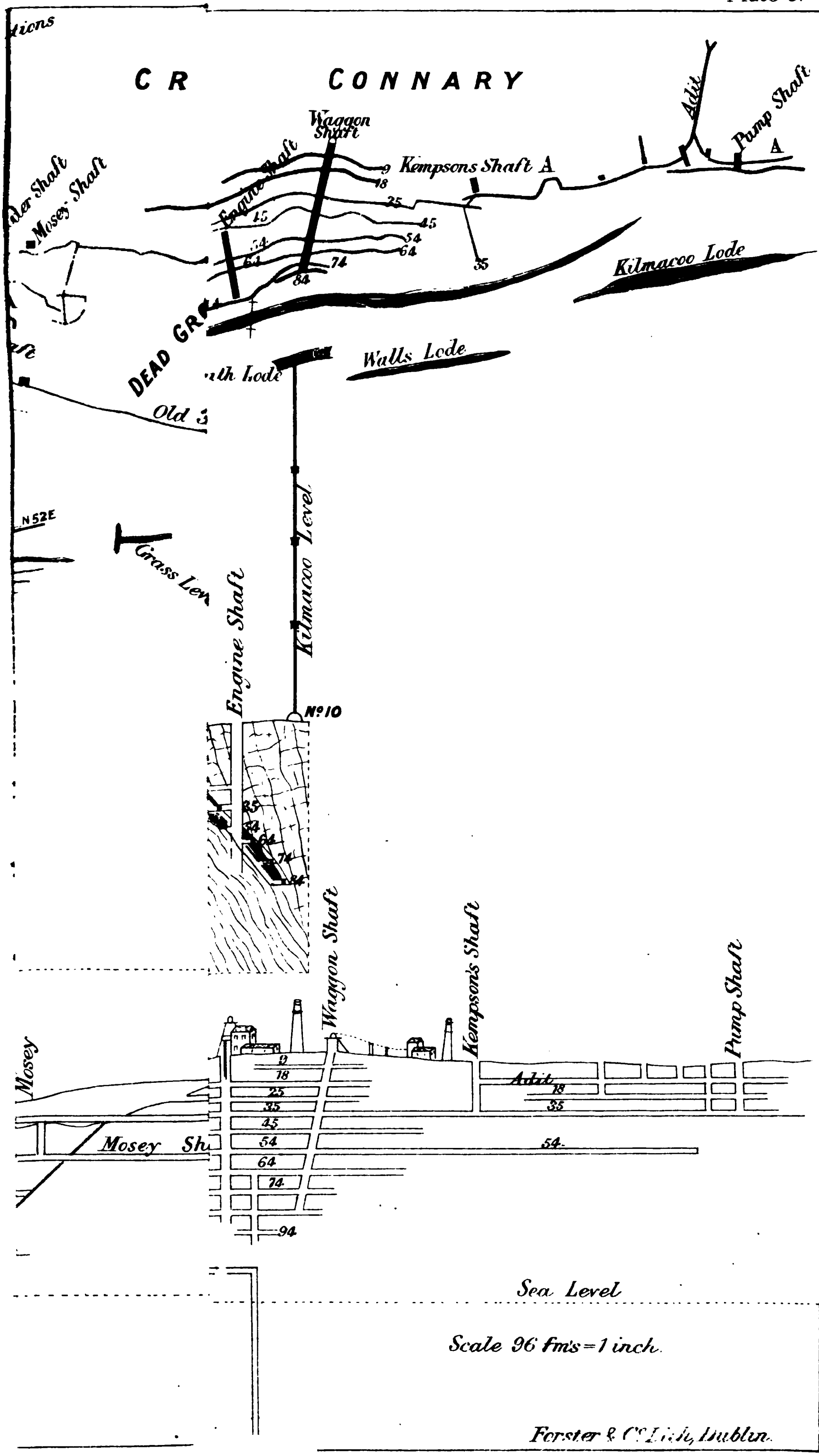
In this head (N. 32° E.) the felstone forms the hanging wall of the lode, while its filling stuff is nearly entirely white felspathic clay, instead of the "blue steatitic clay," which up to this place formed the principal filling stuff. The chief ore in this part of

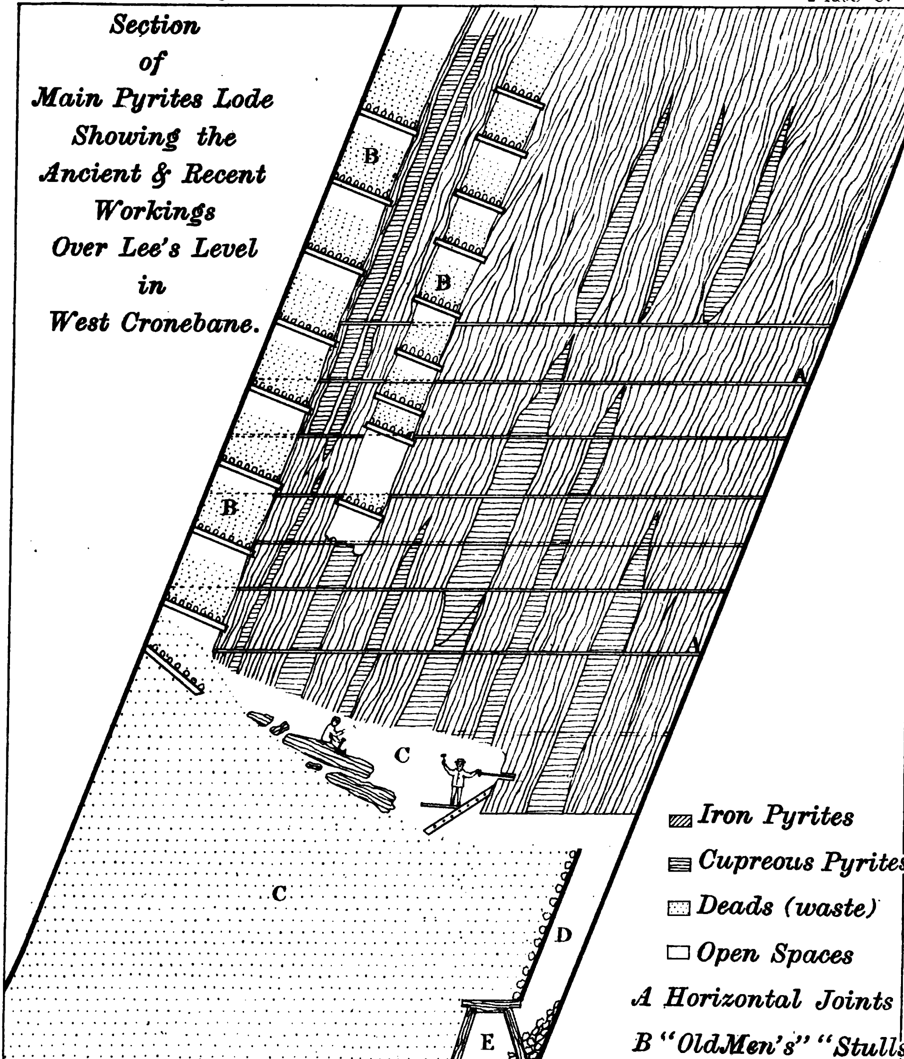
the lode is fahlerz, which occurs in large quantities, and of a high per-centage; associated with it is a little melaconite, and large rounded lumps of galena. No iron pyrites is found, except a few strings, until east of the N. 32° E. head in the *Connary Mine*. Here the north lode is just the same as that described at the Magpie, with the exception that in depth a quartzose rib (Rattle Box) forms the hanging wall. This has disseminated in it specks and strings of copper and chalcopyrite. In the Connary Engine shaft the lode was followed down for a depth of 76 fms. from surface, and 15 fms. east of this shaft a winze was put down 20 fms. deeper, in which the lode was found to be productive for a few fms. below the 84-fm. level, at which place the walls were almost in contact (see cross section No. 10.), while in length the lode was cut out by slides coming in from the east and west. Still deeper the walls came together, completely cutting out the lode, at a depth of 94 fms. from surface, or 24 fms. above sea level. Elsewhere the main lode in this mine has not been proved to its full depth. In length it has not been proved farther eastward than Kempson's shaft, although its gossan has been followed for some distance into Kilmacoo.

South of the Connary main lode, in the townland of Sroughmore, there is a second lode ("Wall's lode"), with a similar bearing and underlie, which for a short distance produces iron pyrites, with a little chalcopyrite. Wall's lode to the east breaks into strings, while westward it is cut off by a mass of felspathic rock. South of Wall's lode on the felstone a quartz lode, similar to the "Rattle Box," with strings of chalcopyrite was proved in the Kilmacoo level.

Farther north-east in Kilmacoo there is a south lode (Kilmacoo lode) principally made up of "soft ground," which contains bunches and veins of "Kilmacooite," which is a peculiar combination of sphalerite, argentiferous galena, iron and copper pyrites, and antimony glance, with a trace of gold. Large quantities of Kilmacooite have been raised from this lode.

The great sulphur lode in these mines (East Cronebane and Connary) is more or less wedge-shaped, gradually narrowing in depth; it has a general bearing of N. 60° E., with a southerly dip of 60°. As previously mentioned, it has been proved to its full depth in the Magpie shaft, and a little east of Connary Engine


CR CONNARY
Waggon Shaft
Engine Shaft
Kempsons Shaft A
Adit
Pump Shaft
A
Moseys Shaft
Kilmacoo Lode
DEAD GR
Walls Lode
Old
N 52 E
Grass Lev
Kilmacoo Level
Engine Shaft
Nº10
Waggon Shaft
Kempson's Shaft
Pump Shaft
Mosey
Mosey Sh
Adit
Sea Level
Scale 96 fm's = 1 inch.
Forster & Cº Lith, Dublin.



or Ancient workings on the Cupreous Pyrites (Stoped underhand)

C Recent workings by which the whole breadth of the lode is taken away and the place filled by running down the deads from the Old Men's Stulls; by this means dangerous falls are prevented. (Stoped overhand)

D "Trap Hole" used for throwing down the ore to the level.

E Level communicating with shaft. (Lee's Level)

H. Argall, Del.

shaft. It is generally supposed to be a continuation of the main sulphur lode in Tigroney and West Cronebane; but as they differ from each other so much in character and composition I am led to believe that the lode in the upper mines (East Cronebane and Connary) is quite distinct from that in the lower mines (Tigroney and West Cronebane). The following are the principal differences:—

Upper Mines.	Lower Mines.
The gossan* occurs in bunches in masses of ferruginous clay, and never occupies the full width of the lode. It contains auriferous silver.	The gossan in mass occupies the the full width and length of the lode. No trace of auriferous silver can be found in it.
"Coal ground" occurs in large masses.	No "coal ground" occurs, except in minute quantities.
The iron pyrites never fills the lode, but occurs in cakes or lenticular masses in the filling stuff. The iron pyrites does not become coppery in depth. The clays or "soft ground" that forms the filling stuff of the lode continues soft down to its full depth.	The iron pyrites nearly invariably occupies the full width and length of the lode; in depth it becomes coppery. Near the surface there is a little soft ground, but none is found in depth.
The country on the north and south of the lode, except the felstone in the Lodge level, is very little mineralized.	The country on the north and south of the lode is more or less mineralized, especially the latter, in which occur copper lodes for a width of 25 fms. from the hanging wall.

The associated country rocks of the lodes in the two places are also different; the bearings of the lode are also different, as follows:—*Tigroney Mine*, from the great flucan to the reversed fault, N. 65° E.; from the reversed fault to the boundary fault, N. 70° E. *Cronebane West*, from the boundary fault to the "Dead Ground," N. 85° E. *Magpie Mine* to the N. 32° E. head, N. 60° E.; along the head to *Connary Mine*, N. 32° E.; from the N. 32° E. head to Kilmacoo, N. 60° E.

The mineral channel at Kilmacoo is possibly heaved northward about 1,000 fms. by the Kilmacoo east head, for at that distance northward to the east of the head, in the townland of Rockstown, are "shode stones" and lodey indications; they, however, as yet

* This gossan could not be shown in detail in the cross sections owing to the smallness of the scale; therefore the gossan and ferruginous clays are shown as gossan.

have not been explored. The country to the east is also heaved northward by this head.

In the hollow occupied by the road from Kilmacoo to Kilmacrea Pass there is a N. 75° E. course of flucany killas with thin veins of iron pyrites; on it trials have been made without finding any profitable lode. The tract of country east of Kilmacoo East head is very much broken up; many more or less isolated masses of felspathic rock (felstones, hornstones, and tuffs) occurring therein.

The Kilmacrea cross course is an irregular dyke of black (coaly) and gray killas with hard gritty ribs running with the bearing of the course; at the north end of the course there are "old men's workings" consisting of a nearly E. and W. level and different shafts. Some trials were also made about seventeen years ago without any practical results. The level is evidently very ancient, and little is known about it. Close to the Crossroads is Brady's shaft in which broken sulphur ore was found in a "lodge," while a little farther south is Foley's shaft where yellow ore is said to have been raised; here, also, the site of the old "cobbing" floor is pointed out. This ore may possibly be a rib associated with the "coal." About 83 fms. farther south, in a small trial at the road, there is a sparry string carrying some sphalerite; while about 90 fms. still farther south there are blocks of coppery quartz that seem to belong to nearly a E. and W. lode in the wood.

From Kilmacrea cross course to the N. 10° W. fault in Ballycapple Hill, a distance of 1,000 fms., the country is also much displaced, and no mineral indications are known therein except a few iron springs and some quartz tumblers containing chalcopyrite—which are found in Ballykean at a considerable distance south of the bearing of the mineral channel of Connary.

Ballycapple and Ballard Mines.

In the eastern side of Ballycapple Hill several pits were put down, and open casts made to reach the gossan of the lode, which is a powdery, blackish-brown ochre containing pyrolusite. The lode as seen in these pits runs E. and W., and is 16 feet wide, with a southerly dip of 90°; the best gossan is found on the foot-wall, and is about 6 feet wide, resting on which is 2 feet of a hard grit rib, south of which there is 8 feet of gossan. The

lode has been proved for 135 fms. from the brow of Ballycapple Hill eastward, where it is heaved southward by a left-hand displacement of a few fms.; while 20 fms. east of this displacement the lode is cut by a N. 10° W. head that underlies to the east. East of the N. 10° W. head the lode is continuous for about 50 fms., where it meets with a right-hand displacement (reversed fault), which lengthens the lode. From the "reversed head" the lode is continuous for 135 fms., at which point it is displaced by the "middle head," a distance of 200 fms.

Between the N. 10° W. head and the middle head the lode was in places extensively worked by the "old men;" their workings, that are known, being four large circular pits called the *Clash pits*,* and an adit level driven in from the south capable of unwatering them to a depth of 12 fms. The works seem to have been stopped abruptly, as this level although within a few fms. of the pits never holed them.

Within the last three years two shafts were sunk west of the "reversed head," proving a standing lode 4 fms. wide for a depth of 7 fms.; these two shafts were connected by a level, and 800 tons of ore extracted. Sixty-six fms. east of the "reversed head" a shaft was also sunk for 6 fms.; in it the lode was vertical for 4 fms., and 3 fms. wide, after which it dipped south at 70°, and the ore increased in width and quality. In *Ballard Lower* to the east of the middle head the lode seems to extend E. for 100 fms. Here iron ore was also extracted; there being the remains of four circular pits; but no mining has been carried on during later years, and nothing further is known about the lode.

The bearing of the portions of the lode in Ballycapple and Ballard is about E. and W. The gossan, as far as known, is a powdery, dark-brown ochre in which large tumblers of chalybite occur; the ore itself contains a large per-centage of magnetite, and gives about 56 per cent. metallic iron, and 4 per cent. manganese.

* The *Clash pits* were worked for iron ore over 200 years ago; there is a tradition in the country that copper ore was also found. They probably received their name from Ballynaclash, generally, called Clash (in the Glenmalure valley), where there was an iron furnace and works, and to which place the ore was carried on horseback.

NOTE ADDED IN THE PRESS.

The following analysis of "Kilmacooite," or Blue Stone, will show the general composition of this interesting mineral:—

—	A	B	C	D	E
Lead,	15·90	15·52	7·60	15·42	26·10
Copper,	3·58	2·77	3·17	0·20	00·55
Iron,	16·45	4·40	27·40	2·50	11·56
Antimony,	0·10	–	–	–	–
Arsenic,	0·13	–	–	–	–
Zinc,	26·18	24·00	8·16	49·08	20·00
Sulphur,	32·65	20·18	37·12	28·56	24·60
Silica,	0·82	30·90	12·00	2·50	16·70
Earthy Matrix,	3·65	–	–	–	–
Oxygen,	0·50	–	–	–	–
Gold,	0·001	–	–	–	Trace.
Silver,	0·012	–	–	7½ oz.	6 oz.
Loss,	0·27	–	–	–	–

A. Ore from Pary's mountain Mine.
B. Ore from Madam Butler's lode, Cronebane.
C. Ore from main lode at Butts shaft, „
D. Ore from south lode at Old Whim shaft, „
E. Ore from Kilmacoo lode (Connary mine).

The iron pyrites in the main lode at the Magpie mine contains more or less lead, and in places zinc, and so graduates into "Kilmacooite." C is an analysis of iron pyrites changing into Kilmacooite.

The Chalcopyrite found in the Eastern Ovoca mines contain from 8 to 12 per cent. of copper.

The iron pyrites contain from 33 to 36 per cent. of sulphur. About one-sixth of the pyrites is cupreous, and contains 38 per cent. sulphur and $2\frac{1}{8}$ per cent. copper. Nearly all the pyrites contains gold, silver, nickel, and cobalt, in small quantities.

B, C, D, and E were not tested for antimony or arsenic; they, however, are probably present in B, D, and E.

B and C were not tested for silver or gold.

XIX.—DINGLE BEDS AND GLENGARIFF GRITS, BY G. H. KINAHAN, M.R.I.A., &c. PLATE 7.

[Read 21st April, 1879.]

FROM the comments that have been made on my representation of the relation between the Dingle Beds and the Glengariff Grits, with the accompanying diagrammatic section in *Chap. IV.* of my book on the *Geology of Ireland*, it would appear that some further explanation of the subject is necessary, and this I now propose to give.

But first I would refer to the recently published paper on "The Old Red Sandstone of Western Europe," by Dr. A. Geikie (*Trans. Roy. Soc., Edin., vol. xxviii., p.* 345), as his statements in reference to the "Old Red Sandstone" of Scotland have particular bearing upon the present question. In p. 347 of that paper he states :—

(1.) "My own work in the centre and south of Scotland had proved the Old Red Sandstone to consist of two great divisions—a lower passing down conformably into the Upper Silurian shales, and an upper graduating upwards into the Lower Carboniferous."

And at page 353 he affirms, when contrasting the uniformity of the stratified rocks of Silurian age with the Old Red Sandstone :—

(2.) "No such general uniformity of stratification presents itself in the Old Red Sandstone. On the contrary, with the accumulation of the deposits in limited basins, come local and often peculiar features, whereby even contiguous tracts are distinguished from each other. It is still possible roughly to make out with more or less clearness the limits of the basins, &c."

These remarks, as I have shown in a former paper, are very applicable to the corresponding Irish rocks ; as everywhere, except in S. Kerry and Cork, those Irish rocks, like those called by Dr. Geikie "Upper" and "Lower Old Red Sandstone," are discordant with each other; while everywhere the *Upper* graduates into the Carboniferous, and in different places the *Lower* into the Silurians. We also find great lithological differences in the rocks of the different areas or basins. Geikie at page 354 divides the rocks classed by him as the "Lower Old Red Sandstone" of Britain into five great "Basins of Deposit." Of these, No. 4 he calls the

deposit of "the Welsh Lake" basin; and on looking at a Geological map of Great Britain and Ireland, it is evident that the rocks which form the subject of this paper are part of those accumulated in the western portion of this basin.

Let us now return to the Dingle and Glengariff rocks. Although Griffith classed them with the Silurians, while Jukes would class them with the Old Red Sandstone, yet both would seem to agree* that the Dingle Beds are equivalents of the older portion of the Glengariff Grits, or, as Griffith affirmed before the Society, the visible Glengariff Grits *as a mass* are higher up than the visible Dingle Beds *as a mass.*

These observers also agreed that while the Dingle Beds are capped unconformably by the "Old Red Sandstone,"† the Glengariff Grits extend upwards conformably into that group, and thence up to the Coal Measures.

The Dingle Beds at the westward of the Dingle Promontory, as indicated in the accompanying diagrammatic section, are at least 10,000 feet thick, but eastward higher beds come in. The Glengariff Grits south of Dingle Bay, as far as seen, are of somewhat similar thickness; though they are doubtless complete, yet the lower 3,000 or 4,000 feet, which rest on the Marine Silurians, are not exposed.

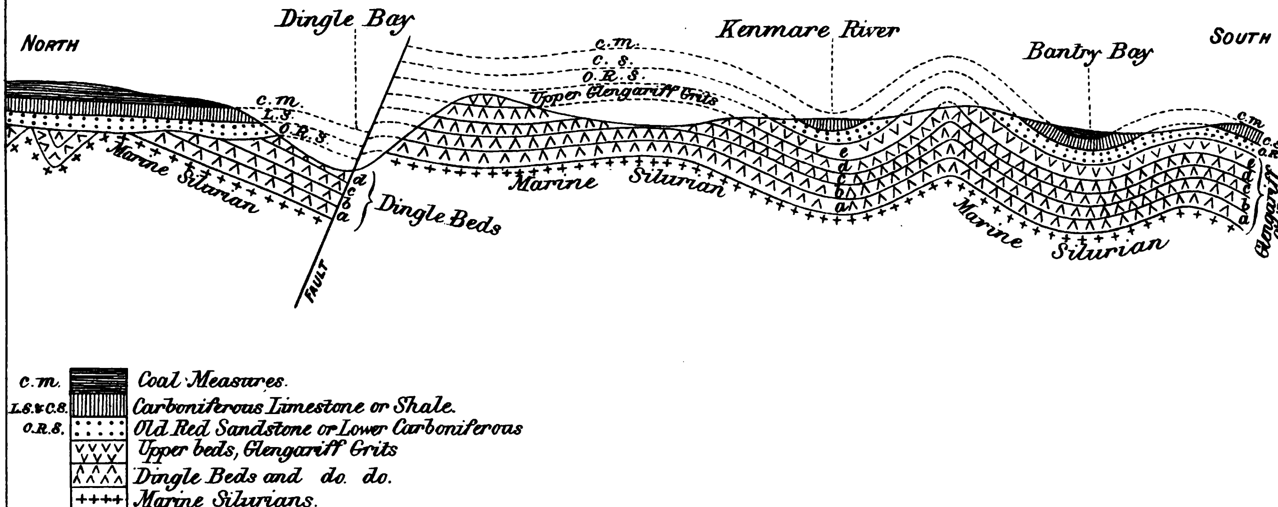
It is evident that a nearly E. and W. fault, having a down-throw to the northward, extends along the valley of Dingle Bay; and that it has a considerable throw, of at least 5,000 feet, is proved by the position of the Coal Measures near Killorglin, which probably are in juxtaposition with the Glengariff Grits that underlie the tract of "Old Red Sandstone" on the south of the fault.

The place in about which this fault (*Dingle Bay fault*) occurs is indicated in the diagram. There are also other lines of fault that extend from the Lakes of Killarney to Dingle Bay; but in the diagram, these and others that occur farther southward, as also the undulations and minor breaks, are not represented; the horizontal distances, however, are correct—that is, the distance from the centre of Dingle Bay to the centre of Kenmare river (24

* Memoirs Geol. Survey, Exp. sheet 182, *f.n.* page 10.

† Here and elsewhere in this paper the Upper or Carboniferous Old Red Sandstone will be mentioned under the title of "Old Red Sandstone," while the Lower will be called either "Glengariff Grits" or "Dingle Beds."

Diagrammatic section showing the relations between the rocks North and South of Dingle Bay.



G. H. Kinahan, Del.

Forster & Co. Lith. Dublin.

miles), and from the latter to the centre of Bantry Bay (14 miles). There is a distance of about sixteen miles from the outcrop of the "Old Red Sandstone" south of Dingle Bay to the outcrop of the "Old Red Sandstone" on the north of the Kenmare river.

In the diagram it is shown that near Dingle there is a thickness of "Dingle Beds" represented by the strata *a*, *b*, *c*, and *d*, which are also repeated in the country to the south; but to the south, in addition to these, are the strata marked *e*, on which the "Old Red Sandstone" lies conformably. We have therefore now to account for the fact, that while the strata *e* were accumulating in the country south of Dingle Bay, no contemporaneous beds were laid down on the other side of that bay in the western portion of the Dingle Promontory.

It would appear that, for a time after the deposition of the marine or typical Silurians, there were successive accumulations of matter, represented by the strata *a*, *b*, *c*, *d*, over the whole of this portion of S.W. Ireland; but that after the beds *d* were deposited a great disturbance took place in the region N. of Dingle Bay, the southward boundary of which ran along what is now the valley of Dingle Bay, or there may have been a fault along that line, with an upthrow to the north.* This would cause the rocks in said region to be upraised, and brought under the influence of the denuding agencies; but whilst this was taking place on the northward side of what is now Dingle Bay, rocks were still being continuously deposited on the southward side, and the strata represented by *e* were accumulating.

But after the rocks *e* were deposited in the south country, the denudation of the strata in the north country ceased, and then the "Old Red Sandstone" began to be deposited and gradually spread over the whole region, and upon it again were laid down ever conformable deposits, up to the Coal Measures. In support of this hypothesis we find in the sections published by Jukes, that the "Old Red Sandstone" to the south is thicker than that to the north; also that on the Silurian and Dingle Beds the "Old Red Sandstone" is of unequal thickness, while still farther northward it gradually thins away.

At the beginning of this communication attention was directed to Geikie's observations as to the different basins of the Scotch

* See note in Press.

rocks, having marked lithological differences. This is also applicable to the "Old Red Sandstone" of Cork and Kerry; but at the same time in these counties there seems to be no very sudden change, as almost invariably the rocks of one type graduate into those of the others, while certain peculiarities are very constant. The most constant character seems to be the "Metalliferous Beds" in the upper portions of the "Old Red Sandstone." These are best developed in the country south-east of Bantry Bay, but they are also well marked in the country north and south of Kenmare River, and can be traced eastward from Cork into Waterford and Kilkenny; while northward they are found in the Tralee district, and farther north margining the Kerry Head tract of "Old Red Sandstone;" and to the east of the co. Kerry, traces of them can be observed in the "Old Red Sandstone" of the cos. Limerick, Clare, and Tipperary.

On the north side of Dingle Bay the lower portion of the "Old Red Sandstone" is more or less conglomeritic, and the same character is found on the south side in Iveragh, immediately adjoining Dingle Bay. In the latter country the most typical conglomerates occur to the west, at Doulus Head, while eastward the rocks gradually lose this character, and at Killarney they have assumed many of the West Cork types. When, however, we proceed eastward from Cork into Waterford the conglomeritic rocks again appear; as, however, I have elsewhere fully entered into this subject, it is unnecessary to follow it further.

Subsequently to the close of the Carboniferous Period, a rupture took place along the line of the Valley of Dingle Bay, extending eastward along the Flesk and Blackwater Valley, which was evidently a downthrow to the northward.* It is along, or nearly along, this line that we have contemplated a great antecedent flexure, or a fault with an upthrow to the northward. It is readily conceivable that here, as elsewhere, along great lines of successive faults, this newer displacement along the same line of weakness need not by any means have necessarily the same horizontal extent, any more than it must have a constant amount of vertical throw. The downthrow to the north of this newer fault

* Associated with this were branch faults, one conspicuous one, extending from the Killarney Lakes to Glenbehy, on Dingle Bay; it is, however, unnecessary to go into these now.

varies in magnitude in different places. Near Millstreet it seems to bring down the Coal Measures against the Glengariff Grits; but eastward of this the throw is much less; and a little westward it is also less, but it increases again as we proceed farther west to Killorglin, where there is a patch of Coal Measures, which have possibly been brought down against the Glengariff Grits, which are there covered by the "Old Red Sandstone;" still farther westward it again decreases.

In conclusion, I should point out that in the Dingle Beds the fossils, as yet found, are more or less obscure markings, that may belong either to land plants or fucoids. South of the bay at Valencia Lighthouse there are tracks suggested by Baily to be those of crustacea; they are, however, very similar in aspect to the tracks made by the grey gurnet on a sandy bottom. The most important fossils, however, are the plants found in Glanroe, which are distinctly similar to *Sagenaria Veltheimiana* from Tallow Bridge, co. Waterford, and *Knorria Bailyana* from Kiltorcan, both of which localities are in the Upper or Carboniferous "Old Red Sandstones."

Note added in Press—*Vide page* 167.—Those who have studied the writings of Le Conte and others, on the lowering and upheaval of strata, can readily understand that, although it is probable a fault or faults occurred at this time in the area of Dingle Bay, yet it or they are not absolutely necessary, as the rocks to the northward may have been crumpled and raised up, so as to come under the influence of denudation without a break having taken place.

XX.—NOTES ON THE DISCOVERY IN IRELAND OF A BONE CAVE CONTAINING REMAINS OF THE IRISH ELK ASSOCIATED WITH TRACES OF MAN, BY R. J. USSHER AND PROFESSOR LEITH ADAMS.

[Read May 19th, 1879.]

NOTE FROM PROFESSOR LEITH ADAMS.

I HAVE much pleasure in being enabled to announce the discovery of a new bone cavern in the south of Ireland, regarding which I have no doubt that the Fellows of the Society will be interested to know a few particulars. During the Easter holidays, when on a visit to my friend, Mr. Ussher of Cappagh, he directed my attention to a cave in the neighbourhood, about seven miles distant from the famous Shandon Cave, which I explored some years ago.

Mr. Ussher's researches in the above cave, although prosecuted during a few days only, have eventuated in the finding of stone implements of the Neolithic period, accompanied by bone implements, rubbers, &c., and the remains of the Irish elk, bear, deer, &c.

The association of evidences of man with undoubted remains of the Irish elk, whose bones he had smashed and formed into implements, is now proved in Ireland for the first time, by this discovery, of which I was an eye-witness. The cavern in question is of large size, and appears to have been occupied at one time by man, and previously by bears, as entire jaws and portions of skeletons of the latter are met with in the lower deposits of the floor.

Mr. Ussher proposes continuing his explorations, and will report the results to the British Association for the Advancement of Science, with the view of obtaining a grant to enable him to clear out the contents of the cave. I hasten to mention this discovery now, as I know how the Fellows of the Royal Geological Society of Ireland will welcome the results of Mr. Ussher's most praiseworthy exertions.

May 5, 1879.

NOTE FROM MR. R. J. USSHER, OF CAPPAGH.

I have just spent three days at the cave, excavating outside it. Monday was almost entirely consumed in removing the heap of rubbish we had thrown out last month. In doing this we found some bones that were then overlooked, among them a very large phalanx and a claw of bear. Yesterday and to-day we have been digging the deposits outside the entrance. There are continuations of the side walls of the cave running outwards for some distance.

The upper stratum is dark earth, under which comes a lighter layer. Under that, hugo blocks of stalagmite, extending at least ten feet outwards from the entrance of the cave. They were disconnected, and coated with the pale sort of earth, No· 3 (?), in which they lay. One block measured three feet six inches by three feet, and was over a foot thick. At places near the sides on this level were deposits of gravel and pebbles. We have removed all these great blocks, and are now working downwards into the cave, out of which you can now walk on the level. We found bones in all the layers, chiefly at the sides and in crevices of the flanking walls.

I got a bear's canine yesterday in the upper horizon of the second (grey) stratum outside the cave.

There are various teeth of ox and pig, numerous bits of bones of Irish elk, some of the latter split.

I got a very ancient-looking bone (probably bear) among the blocks of stalagmite to-day, eleven feet outside entrance, very deep down.

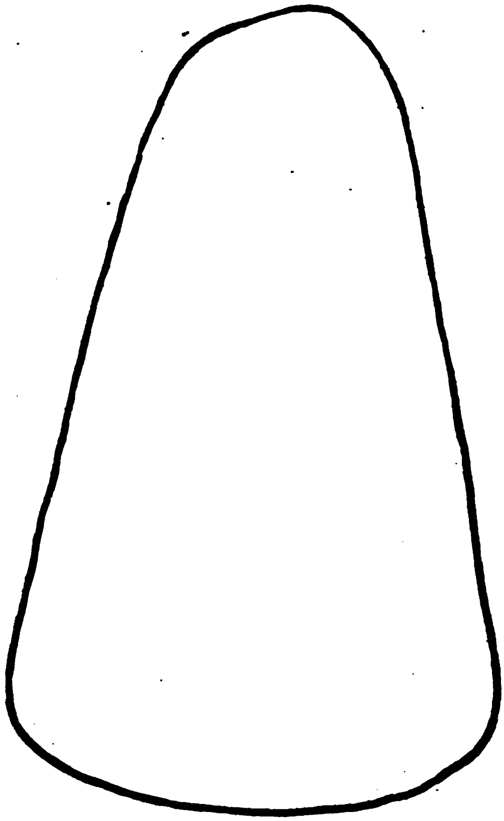
Charcoal is continually occurring, even among blocks of stalagmite, at four and a half feet below the surface.

The most interesting find was a large flattened *bead*, of some transparent substance of the colour of brown sherry. It was found in the upper stratum, close to where we got the celt, an outline of which latter is given on the next page.

A little farther in, at four or five feet deep, we got (with bones of Megaceros and charcoal) a number of lumps of rounded limestone, with pits like the eyes of a potato. One resembled a

potato exactly in form. One of these has two groups of indentations, three in each plainly made by man. I hope to continue working inwards on Friday, if fine.

May 14, 1879.



Greenstone celt found in the cave at Cappagh, with bones and pieces of horn of the Irish Elk (natural size).

XXI.—A PROBLEM FOR IRISH GEOLOGISTS IN POST-GLACIAL GEOLOGY, BY T. MELLARD READE, C.E., F.G.S., F.R.I.B.A.

[Read June 16th, 1879.]

A VERY careful examination of the Post-Glacial Beds on the coasts of Lancashire and Cheshire in 1871,* led me to the conclusion that there are remains of two land surfaces which are later than the laying down of the Marine Glacial Drift.

Subsequent observations have tended to confirm this opinion; the excavations at the Garston Dock, on the east side of the Mersey, five miles above Liverpool, and at the new Bootle Docks at the entrance of the Mersey, having thrown considerable light on the subject.

Shortly stated, the surface of the Boulder-clay near the margin of the River Mersey is, in various places, cut into gullies reaching, in some cases, to a greater depth than the level of low water, and these again are filled in with marine silts and sands belonging to a system I have named the Formby and Leasowe Marine Beds, represented by a large extension of Scrobicularia clays and silts below the 25-feet contour on the coasts of Lancashire and Cheshire, and usually covered by a bed of peat containing stools of trees *in situ*.†

The following is a complete section taken across one of these gullies where it intersected the Garston Dock.

No. 1. Triassic rock. (Bunter Sandstone.)

1A. Red Sand, debris of the above (probably ground moraine). } Glacial.

2. Marine Boulder-clay containing striated boulders and pebbles of foreign rocks. } Glacial.

* Post-Glacial Geology of Lancashire and Cheshire. Proceedings of Liverpool Geol. Society.—Session 1871–2.

† Quarterly Journal of Geol. Soc. Vol. xxxiv., pp. 147–8.

3. Coarse flesh-coloured sand, 4. Yellow Sand,	Formby and Leasowe Marine Beds.	Post-Glacial
5. Peat with stools of trees *in situ*,	Superior peat-and-forest-bed.	
6. Recent silt containing *Scrobicularia piperata in situ* (showed interesting examples of cross laminations at all angles, with partings of comminuted peat).		

7. Sand containing Tellina, Turritella, &c., forming shore of the River Mersey.

Nos. 3 and 4 were divided from each other in places by a bed of peaty matter a few inches in thickness, which I consider of no geological importance.

It is quite evident that the gulley, as shown in these sections, could not have been excavated by the stream under present conditions of level of land and water. The inference from this and numerous other examples which it is not necessary to detail here, is that when the gulley was excavated in the Boulder-clay the land stood higher than at present. At Dove Point, Cheshire, was to be seen, and probably still is, a land surface corresponding to this period (see section M to N, Detail sheet of Sections in Post-Glacial Geology of Lancashire and Cheshire), with the Scrobicularia clays (Formby and Leasowe Marine Beds) lying upon it, and above that another land surface representing the Main beds of peat with stools of trees *in situ*.

If we follow out the chain of events of which these remains are the consequences we shall find that the gullies in the Boulder-clay and rock and the Lower or Inferior peat represent a period of elevation of the land (of undetermined extent), the Marine silts a period of depression, and the Main or Superior peat bed another period of comparative elevation, as proved by the Submarine forests on the coasts of Lancashire and Cheshire, and the recent silts a subsequent and final depression.

All these former land movements I consider are clearly established by the evidences of various sections I have had the opportunity from time to time of personally inspecting. Of the limits of their horizontal extension it is impossible to speak with so much certainty, but, from the numerous examples of peat beds

and stools of trees found at almost every estuary in Great Britain, from the Land's End to the Orkney Islands, and from similar examples to be found in Ireland and on the coast of France, two of the movements must have been very widespread.

The problem I would wish to place before Irish Geologists is this —Are there evidences of land movements, similar to those I have described on the West Coast of England, to be found in Ireland? and if so, to what extent?

No very detailed account of the Post-Glacial deposits of the estuaries of Ireland has come under my notice; but I trust that when attention has been called to this subject it may be worked in a more systematic manner; as it is probable much light would thereby be thrown on the period of time subsequent to the Glacial era.

Mr. Kinahan, in his Manual of the Geology of Ireland, in a chapter on "Submerged land and forests," mentions various examples of peat with tree-stools *in situ* occurring below high-water mark, and states that on the East Coast different beaches of this age (the 12ft. beach) lie on the submerged peat, proving that the twelve-feet beach was formed more recently than the submergence." As Professor Hull and Mr. Kinahan adopt a different classification of the raised beaches, it is not always easy to identify them, but I presume the "twelve-feet beach" of Kinahan is "the continuation of the twenty-five-feet beach of Scotland" of Hull.* Mr. Kinahan also refers to a submerged bog, "discovered by Dr. C. Farran at Clonca, near Dungarvan, after one of the highest tides known in the country." "Here are the remains of an ancient pine forest, miles in length, now usually covered with many fathoms of water."

I think it extremely probable that these submerged forests of Ireland are synchronous with the Main or Superior peat-and-forest-bed of Lancashire and Cheshire. This often has, as in Wallasey Pool, the site of the present Birkenhead Docks, a considerable depth of recent marine silt lying upon it, in which we find horns of the red deer, bones of cetaceans, and other mammalian remains. The surface of this silt is so little raised above ordinary high-water level that it must have been laid down approximately at the present levels of land and water. As we go

* Physical Geology and Geography of Ireland.

further north there does, however, appear to be evidences of the land having been lower than at present. There is the raised beach, or rather shell-bank, on the shores of Morecambe Bay, a few feet above high water; and at St. Bees, further north, I found in 1872 what I consider Post-Glacial deposits, corresponding to the Formby and Leasowe Marine Beds, at an elevation of from eight to nine feet above high water. All these facts point to a gradual elevation northwards; and in the estuary of the Tay and other Scotch rivers the "links" consist of sand and silts overlying peat, containing remains of trees.* It is, therefore, not improbable that this may be the result of one earth movement. If my supposition be correct the raised estuarine deposits of Scotland are subsequent to the Superior peat-and-forest-bed of the North-West of England, and synchronous with the last of the raised beaches (containing worked flints) of the east coast of Ireland; and the more recent of the marine silts, such as those of Wallasey Pool, overlying the Superior peat-and-forest-bed, are of the same age.

Should these suppositions prove correct it now remains to discover if there exist in Ireland the equivalents of the Formby and Leasowe Marine Beds, which underlie the Superior peat, and also the remains of the land surface upon which I have shown they rest.

If these few observations should induce any of the Irish geologists to turn their attention to the subject, I shall be very glad, and I am quite sure it is well worth investigating.

* The Last Geological Changes in Scotland (Jamieson), Quarterly Journal of Geo. Soc. for August, 1865, pp. 188–190.

XXII.—NOTES ON THE ANNUAL WATER-DISCHARGE OF LARGE RIVERS; WITH INDICATIONS OF SOME NEW METHODS OF CALCULATION, BY REV. SAMUEL HAUGHTON, M.D., D.C.L., F.R.S.

[Read May 19th, and June 16th, 1879.]

NOTE I.

On the Annual Water-discharge of the Ganges, Brahmapûtra, and Irawady.

The Rev. Mr. Everest, in 1831–32, instituted a series of observations and experiments on the Ganges, at Ghazipûr, a little below Benares, and 500 miles from the mouth of the river, at the Hoogly.

From these experiments, the following facts were obtained:—

Water-discharge.

	Cubic feet per second.
Rain (4 months),	494,208
Winter (5 months),	71,200
Hot weather (3 months),	36,330

The arithmetical mean of these figures for the whole year is, obviously, 203,485 cubic feet per second; which gives us an annual water-discharge of 43·625 cubic miles.

Now, the total length of the Himalayan ridge drained by the Ganges is 670 miles, and the rainfall increases from west to east: but the Ganges, at Ghazipûr, has received the drainage of only 150 miles of the western end of the ridge. Sir Charles Lyell, following Colonel Strachey, proposed to estimate the discharge of the Ganges into the sea by increasing the Ghazipûr discharge, in the proportion of 670 to 150, or to nearly 4½ times the Ghazipûr discharge.*

As this appears to me a very rude method of calculation, I have recomputed the areas of the rain-basins of the Ganges, above and below Ghazipûr; and of the Brahmapûtra, using for the purpose Mr. Stanford's newest Orographical Map of Asia.

I traced carefully, for this purpose, the three areas mentioned,

* *Principles of Geology* (Lyell), vol. i., p. 480: London (1875).

and also the area on the map lying between 20° and 30° latitude, and within 10° longitude.

The tracings were then carefully cut out and weighed, with the following results:—

(1.) Rain-basin of Ganges above Ghazipûr (*weight of tracing*) . . . = 0·2265 grm.
(2.) Rain-basin of Ganges below Ghazipûr (*weight of tracing*) . . . = 0·2780 „
(3.) Rain-basin of Brahmapûtra (*weight of tracing*) . . . . . . = 0·4620 „
(4.) Standard area (*weight of tracing*) . = 0·5150 „

I calculated the standard area at 325,660 sq. geo. miles.* From the above we readily find.

Ganges.

Rain-basin above Ghazipûr = 143,220 geo. miles.
Rain-basin below Ghazipûr = 175,790 „ „

Total, . . 319,010 geo. miles.

Brahmapûtra.

Total Rain-basin, . . . 292,140 geo. miles.

This result gives a total discharge for the Ganges somewhat more than double the Ghazipûr discharge (instead of four or five times), or, exactly—

Annual Discharge = 97·170 cubic miles (statute).

The dry season discharge of the Brahmapûtra, at Gwalpara, near the head of its delta, is given by Major Wilcox,† as 150,000 cubic feet of water per second; and I have calculated (by reducing Everest's discharge of 36,330 cubic feet per second, of the Ganges, at Ghazipûr) the Gangetic dry-season discharge at a point corresponding with Gwalpara, on the Brahmapûtra, to amount to 76,000 cubic feet per second.

If we adopt this ratio, we find, for the probable

$$\left.\begin{array}{r}\text{Annual Water discharge of the}\\ \text{Brahmapûtra, . . . }\end{array}\right\} = 97{\cdot}17 \times \frac{150}{76}$$

$$= 191{\cdot}78 \text{ cubic miles (statute).}$$

* By integrating the expression $r^2 \sin\theta \, d\theta \, d\phi$ between the limits named, where

$$r = \text{radius of earth in geogr. miles} = 3958 \times \frac{60}{69{\cdot}1},$$
θ=north polar distance
ϕ=longitude.

† *Asiatic Researches*, vol. vii., p. 466.

The total annual water-discharge of the Ganges-Brahmapûtra system may be estimated, therefore, at 288·95 cubic miles.*

Sir John Herschel† states (without quoting his authority) that the Irawady delivers, on the average of the whole year, into the sea 35,000 cubic feet per second; of which $\frac{1}{3000}$th part by weight is silt. This amounts to an

$$\left.\begin{array}{r}\text{Annual Water}\\ \text{Discharge of}\\ \text{Irawady,} \quad .\end{array}\right\} = 75\cdot038 \text{ cubic miles (statute).}$$

Mr. Everest found that, during the rainy season, the mud held in suspension by the water of the Ganges at Ghazipûr amounted, on the average, to $\frac{1}{428}$th part by weight of the water-discharge.

If we neglect the mud carried down by the the river during the other eight months of the year, we can find a limit to the rate at which the rain-basin of the Ganges is being reduced by the action of the rainfall.

During the four rainy months the quantity of water passing Ghazipûr is

$$494208 \times 60 \times 60 \times 24 \times 30 \times 4 \text{ cubic feet.}$$

Reducing to cubic fathoms, and multiplying by 6, to reduce to tons,‡ and dividing by 428, to find the weight of mud, we find

$$\frac{494208 \times 60 \times 60 \times 24 \times 30 \times 4 \times 6}{6^3 \times 428} =$$
$$332{,}550{,}000 \text{ tons of mud.§}$$

We can now estimate the number of years required to scrape off one foot from the whole surface of the Gangetic rain-basin above Ghazipûr, by means of the formula

$$x = \frac{2{,}660{,}000 \times A}{T}, \|$$

* This is much greater than the discharge of the *Mississipi-Missouri* system.

† *Physical Geography*, p. 207: Edinburgh (1869).

‡ A cubic fathom of water is six tons q. p.

§ Sir John Herschel (without quoting his authority) gives 534,600,000 tons as the sea-discharge of the Ganges.

‖ This formula is readily deduced from the following facts:—

1. The mean specific gravity of surface rock is 2·66.
2. A cubic fathom of water weighs 6 tons.
3. A geographical square mile contains 1,000,000 square fathoms.

where x = number of years,
A = area of rain basin in sq. geo. miles,
T = annual weight of silt discharged, in tons.

Writing in this formula—

$$A = 143{,}220,$$
$$T = 332{,}550{,}000,$$

we find, for the upper basin of the Ganges,

$$x = 1{,}146 \text{ years}.$$

Or, that *the rainfall of the Upper Ganges scrapes off one foot of rock from the whole surface of its rain-basin in* 1,146 *years.* This result is about half that given for the Ganges by Prof. Geikie, who estimates it at 2,358 years. In all probability Prof. Geikie compared the discharge of mud at Ghazipûr with the whole rain-basin of the Ganges, and so got a doubled result.

If my result be altered in the proportion of the rain-basin above Ghazipûr to the whole rain-basin, we find

$$\frac{1146 \times 319}{143} = 2556 \text{ years},$$

which does not differ much from Prof. Geikie's estimate.

Whatever may be the explanation of the discrepancy, I feel great confidence in the data from which I have obtained my result; which is important in its bearing on the duration of geological time, which it obviously tends to diminish.

NOTE II.

The Annual Water-discharge of the River Plate.

Mr. Bateman's estimate of the December low-water discharge of the Rio de la Plata is given in the following extract from a Report drawn up by him for the Government of Buenos Ayres, 9th January, 1871:—

"The Rio de la Plata, formed by the junction of the rivers Parana and Uruguay, is the widest fresh-water river in the world. Assuming it to terminate in a line drawn from Monte Video on the north to Piedras point on the south (though it is generally described as extending much further), it is 60 miles in width at its mouth. At 60 miles further up it is still 40 miles wide. At Colonia, the narrowest part, and 80 miles from the sea, it is 23

* *Geological Magazine*, vol. v., p. 250.

miles wide. At Buenos Ayres, 100 miles from the sea, 30 miles wide; and just below the junction of the various mouths of the Parana with the Uruguay, 120 miles from the sea, it is 26 miles wide. The volume of fresh water it conveys to the sea is probably exceeded only by the Amazon.

"The total area of the basin has been estimated at 1,250,000 square miles*. The Parana, its chief feeder, takes its rise in Brazil, within the tropics, and is swollen by the tropical rains of that region. At about 27° S. latitude it is joined by its most important tributary, the Paraguay. Some of the branches of this river extend to within 12° of the equator, and are also fed by tropical rains; while others issue from the Cordilleros de los Andes, and are periodically swollen by the melting of the snows which rest on the high points of that range of mountains. For 700 or 800 miles, these mountains shed the waters which fall on their eastern slopes to the Paraguay or the Parana, and some smaller streams from the lower lands of the province of Buenos Ayres enter the Plate near the *embouchure* of the Parana.

"The Uruguay, the other great tributary of the Plate, descends from the central part of South America, draining a vast area, and swollen periodically by tropical rains.

"The detritus, or suspended matter, brought down by these streams, has formed the delta of the Parana, the islands which are clustered about its various mouths, and the shoals of the River Plate.

"It was considered a matter of great importance, as bearing directly upon the question of the practicability of improving the harbour accommodation of Buenos Ayres, to ascertain the volume of these streams, and the quantity of matter which they carried in suspension.

"For this purpose careful measurements have been made during the month of December, 1870.

"The Parana was in its lowest state—a continuous drought of six or seven months having diminished the ordinary sources of supply, and the periodical rise resulting from the melting of the snows of the Andes not having yet commenced. This river is

* This is equivalent to 968,000 sq. geo. miles.

stated to be generally lowest in the month of December, from which time it begins to rise: it is said to attain its greatest height in March, and to continue at nearly its maximum level, with little variation, for several months. At Las Hermanas, between Obligado and San Nicolas, the flood level was distinctly visible at 16 feet 4 inches above the level of the water at the time of my visit, 17th of December, 1870. The river was stated to have remained at this flood level for eight months. Measurements of the river were made at Obligado, and of the various branches lower down, including the Ibucuy, so as to ascertain the actual quantity of water which was flowing into the Plate. It amounted to 520,000 cubic feet of water per second, and this may be considered as the minimum volume of the river. I hope to get further measurements when the river is in a state of flood.

"The Uruguay we have not yet had an opportunity of measureing; but from some particulars of depth and velocity, given by Captain Page in his survey of the river for the United States Government in the spring of 1855, and by computations from the chart prepared for the British Admiralty by Captain Sulivan and others, I venture to calculate that it may approximately be rated at about 150,000 cubic feet per second in its lowest state, making the total minimum volume of water poured into the River Plate, if the condition of low water occur in both rivers at the same time, about 670,000 cubic feet per second—a quantity equal to the mean volume of thirty-three years passing down the Mississippi."

Mr. J. J. Revy, an Austrian engineer, was employed by Mr. Bateman as his assistant in the survey of the River Plate; and he subsequently published (without any authority from Mr. Bateman) a work* containing results deduced from the observations made under Mr. Bateman's directions, without any suitable acknowledgement of Mr. Bateman's rights of ownership.

If Mr. Revy's observations can be relied on, they lead to conclusions of considerable consequence—the most important of which is, that the *mean velocity of the water-discharge at any point of the cross section of a large river is simply proportional to the depth of the river at that point.*

* *Hydraulics of Great Rivers.* London and New York (1874).

This proposition may be illustrated by the following observations made on the Parana and on the Uruguay :—

I.—*Cross Section of the Parana, made near Rosario, on the 25th January,* 1871.

Let v = the mean velocity from surface to bottom at any point, expressed in feet per minute.

d = the depth at any point, expressed in feet..

The mean velocities and depths were taken at nine stations across the river, with the following results :—

Station.	v	d	$\frac{v}{d}$
1°	108·4 ft. per minute.	24·4 feet.	4·44
2	253·8 ,,	68·5 ,,	3·71
3	255·8 ,,	58·5 ,,	4·37
4	241·0 ,,	53·7 ,,	4·49
5	215·3 ,,	49·0 ,,	4·39
6	195·0 ,,	42·0 ,,	4·64
7	172·2 ,,	40·0 ,,	4·33
8	129·2 ,,	33·0 ,,	3·92
9	89·5 ,,	20·0 ,,	4·44
Mean ratio, ...			4·3033

II.—*Cross Section of the Uruguay, made near Salto, on the 3rd February,* 1871 :—

Station.	v	d	$\frac{v}{d}$
1°	79·6 ft. per minute.	13·1 feet.	7·45
2	234·2 ,,	22·0 ,,	10·64
3	261·4 ,,	25·0 ,,	10·45
4	281·7 ,,	29·0 ,,	9·71
5	301·3 ,,	29·8 ,,	10·11
6	329·8 ,,	33·0 ,,	9·99
7	317·5 ,,	30·0 ,,	10·25
8	319·5 ,,	31·0 ,,	10·03
9	333·1 ,,	30·0 ,,	11·10
Mean ratio, ...			9·970

If we assume that the mean velocity of the discharge at any point is proportional to the depth at that point, we may calculate the total water-discharge of the river as follows:—

Let y denote the depth of the river, and x the corresponding distance from the bank of the river; then we shall have, to express the curve of the river-bed,

$$y=\phi(x);$$

also, we have

$$v=ky;$$

where k is the coefficient expressed in the last column of the preceding Tables.

The cross section of any elementary slice of the river is ydx, and the corresponding discharge is

$$v \times ydx,$$

or

$$ky^2dx.$$

Hence,

$$Q=k\int y \times ydx \tag{1}$$

where Q is the total water-discharge; or, finally

$$Q=2k \times y_1 \times A; \tag{2}$$

where y_1 is the depth of the centre of gravity of the cross section of the river, and A is the area of the cross section. Both these quantities may be found, without calculation, by experiments made upon a zinc templet, drawn to scale, representing the cross section of the river.

It is well known that $A \times y_1$ is the volume of water, whose weight denotes the *hydrostatic pressure* upon the river section, regarded as a boundary wall; hence we have the proposition—

The quantity of water discharged by a river in a given time is proportional to the hydrostatic pressure on the river section, multiplied by a coefficient which varies with the river basin.

We may now apply the foregoing to calculate the discharge of the Parana at Rosario, on the 25th January, 1871.

The cross section of the river may be divided into six parts, according to the varying slope of the bottom, as follows:—

Station.	Depth.	Horizontal Distance from last Station.
0°	0·00 feet.	0 feet.
1	12·33 „	860 „
2	24·42 „	97 „
3	73·10 „	110 „
4	59·10	750 „
5	37·75 „	1980 „
6	0·00 „	960 „

The first and last of these sections are triangles, and the others are trapezia. The areas and hydrostatic pressures of the several sections are given in the following Table:—

Section.	Area.	Product, Ay_1.
0° to 1°	5303 sq. feet.	21,790 cub. ft.
1 „ 2	1782 „	16,994 „
2 „ 3	5122 „	141,626 „
3 „ 4	69575 „	1,269,760 „
4 „ 5	95880 „	2,357,550 „
5 „ 6	18120 „	228,015 „
	195,782 „	4,035,735 „

In order to find the discharge, we must multiply the total hydrostatic pressure by $2k$, from equation (2), and divide by 60, to reduce to cubic feet per second. This gives us

$$Q = \frac{4{,}035{,}735 \times 8{\cdot}6067}{60}$$

$$= 578{,}910 \text{ cubic feet per second,}$$

which agrees with Mr. Bateman's minimum result for December, viz., 520,000 cubic feet per second.

The water-discharge of the Uruguay on the 3rd February, 1871, may be thus found:—

TABLE.

Station.	Depth.	Horizontal Distance from last Station.
0°	0·00 feet.	0 feet.
1	18·25 "	220 "
2	34·50 "	1560 "
3	24·33 "	710 "
4	31·00 "	160 "
5	0·00 "	90 "

From this we calculate the following Table of hydrostatic pressures:—

Station.	Hydrostatic Pressure, $A\eta$.
0° to 1°	12,215 cubic feet.
1 " 2	559,250 "
2 " 3	310,790 "
3 " 4	61,627 "
4 " 5	14,415 "
	958,297 "

This result, multiplied by twice the Uruguay basin coefficient for 3rd February, 1871, and divided by 60, gives us

$$Q = \frac{958,297 \times 19·940}{60}$$

$$= 318,470 \text{ cubic feet per second.}$$

NOTE III.

New Method of calculating the Annual Water-discharge of the Nile.

I propose, in this note, to calculate the annual water-discharge of the Nile from the following data:—

1°. *The actual measured maximum and minimum discharge.*

2°. *The actual measurements of depth taken from day to day on the Nilometer.*

Various hydraulic theories lead up to the idea that, in large

rivers, the water-discharge varies simply as the cube of the linear dimensions of the river. This may be readily deduced from the hydraulic theory of the preceding note; where we have

$$Q = 2k \times y_1 \times A. \tag{2}$$

If k be a *constant* depending on the configuration of the river basin only, and if the river section remain similar to itself at the place of observation, then A will vary as the square of the linear dimension, and y_1 will vary as the simple linear dimension; and therefore

$$Q \propto h^3 \tag{3}$$

where h is a linear dimension of the river section.*

The French expedition to Egypt, in 1799–1801, obtained the following results :—

	Cubic Metres per Second.
1°. Maximum discharge in September,	10247
Minimum discharge in June,	678

2°. The average of the two years' measurements on the Nilometer at Cairo give the following depths, measured from an arbitrary zero, to which I have added an unknown quantity, x, to be found from theory and observation :—

The Nilometer at Cairo, 1799–1801.

1. September,	$152 + x$.	7. March,	$48 + x$.
2. October,	$127 + x$.	8. April,	$39 + x$.
3. November,	$105 + x$.	9. May,	$25 + x$.
4. December,	$86 + x$.	10. June,	$24 + x$.
5. January,	$72 + x$.	11. July,	$40 + x$.
6. February,	$58 + x$.	12. August,	$111 + x$.

Let x be the unknown line, to be added to the depths measured from the arbitrary zero, to convert them into h (the *hydraulic mean depth*, or standard linear dimension of the river bed).

If equation (3) be true, we have from the foregoing data—

$$\left(\frac{152+x}{24+x}\right)^3 = \frac{10247}{678}; \tag{4}$$

from which we find

$$x = 63. \text{ q.p.}$$

* This quantity h may be regarded as the *Hydraulic Mean Depth* of writers on Hydraulics.

Substituting for x its value, we obtain the following Table :—

Linear Dimension of Nile, at Cairo, in 1799–1801.

	$h.$		$h.$
1. September, . .	215	7. March, ...	111
2. October, . . .	190	8. April, ...	102
3. November, . .	168	9. May, ...	88
4. December, . .	149	10. June, ...	87
5. January, . . .	135	11. July, ...	103
6. February, . .	121	12. August, ...	174

Form (3), and the preceding Table, we find

$$Q = 678\left(\frac{h}{87}\right)^3. \quad (5)$$

Calculating by this formula, I find

Water discharge of Nile, at Cairo, in 1799–1801, *expressed in Cubic Metres per Second.*

	$Q.$		$Q.$
1. September, . .	10,274	7. March, . .	1,408
2. October, . .	7,062	8. April, . .	1,093
3. November, . .	4,882	9. May, . . .	702
4. December, . .	3,406	10. June, . . .	678
5. January, . .	2,533	11. July, . . .	1,125
6. February, . .	1,824	12. August, . .	5,424

$$\text{Total mean discharge} = \frac{40{,}411}{12}$$

$= 3{,}367{\cdot}6$ cubic metres per second.

$= 4{,}404{\cdot}9$ cubic yards per second

$= 118{,}932{\cdot}3$ cubic feet per second.*

$= 25{\cdot}49$ cubic miles per annum.

* Talabot's elaborate estimate, which was adopted by Sir John Herschel, is 101,000 cubic feet per second.

XXIII.—ON THE OCCURRENCE OF MICROCLINE FELDSPAR IN THE DALKEY GRANITES, BY J. P. O'REILLY, C.E., M.R.I.A.

[Read June 16th, 1879.]

WHILE engaged last summer in taking the directions of the main lines of jointing which traverse the Granites of Dalkey Island, my attention was attracted to the peculiar manner in which the Feldspar crystals have withstood the action of the weather, standing out from the rock mass in strong relief, while the accompanying quartz seems to have been eaten away with relative facility, contrary to what might be expected to occur, considering the composition of these constituent minerals, their relative hardnesses and resistances to solvents.

On examining some of those crystals of Feldspar, of which the faces were sufficiently complete and even, I was unable to recognise the usual physical characteristics indicative of an orthose crystal.

Furthermore, I was able to recognise in the crystal, when cut transversely, a peculiar transversely banded chequered structure which led me to imagine that the crystals might possibly be twin forms, according to the Baveno law.

As this form is not usual, at least in the Granites of this country I thought it might prove interesting to further examine the crystals under the microscope, I accordingly had these slices prepared from the two crystals, by M. Emile Bertrand, of Paris, whose skill as a mineralogist, and whose experience in mineral preparations, is well established.

He returned me the samples prepared, declaring them to be very fine specimens of Microcline Feldspar, the properties of which mineral they markedly present under polarized light.

I have since examined crystals from the Granites on Killiney Hill, and in the quarried stones now being furnished to the

contractor of the Rathmines and Pembroke Main Drainage Works, and which are being piled along the wall between the Pigeon-house Fort and the Poolbeg Lighthouse, coming, I presume, from Bullock; and judging from the similarity of the appearances presented by the basal cleavage faces of these crystals, as compared with those recognisable on the similar cleavage face of the sliced crystals of microcline, I am disposed to conclude that the granites of Dalkey are largely made up of this Feldspar—the physical and chemical characteristics of which were so thoroughly determined by Descloiseaux, in the original memoir, published in 1876, in the "Comptes Rendus," Vol. 82, No. 12, p. 885, and in the "Annales de Physique et Chimie," 5me Série, T. IX., 1876.

This latter notice is the more extended and complete, containing photographic illustrations which render comparison with specimens under examination relatively easy and satisfactory.

One of the most remarkable optical characteristics of this mineral is the chequered transverse banded structure (*structure quadrillée*) presented by the thin sections made parallel to the basal cleavage, and which is so markedly apparent in the sections from the Dalkey Feldspars. The Fig. No. 10, p. 436, of the memoir in the Ann. de Phys. et Chim., comes so very near in appearance to that of my drawing, that both illustrations might be taken as having been made from the same crystal.

The essential conclusions arrived at by Descloiseaux in his masterly memoir, are:—First, that Microcline Feldspar is a dimorphic form of Orthose Feldspar, and triclinic in system. Second, that while up to the present Orthose Feldspar has been regarded and taken as the essentially potash Feldspar, it is the microcline variety which really holds that position, since the highest percentage of soda in the microclines analyzed by Damour and Pisani, and selected by Descloiseaux, as published by him in his Memoir, had not exceeded 3·95%, with a minimum in potash of 10·95%. On the other hand, it is a well-established fact, that certain varieties of orthose contain as much soda as potash, so that the limits between the orthose and the albite, as regards composition, are much less broadly marked than between the microcline and the orthose.

Descloiseaux further points out the resistance which the microcline opposes to decomposition, an observation which quite agrees with the state in which the crystals present themselves in the Granites of Dalkey Island.

From the point of view of Geology, this dimorphism of the potash Feldspar merits consideration, since it is well established that dimorphism in a mineral implies distinct conditions of formation for the one and the other form. It may be asked is there not a distinction to be made between granites rich in Microcline Feldspar and those in which either orthose or albite are more prominent as a constituent, and may not such a distinction assist in better characterizing the granites in general relatively to their conditions of formation.

That the Granites of Dalkey are Microcline Granites would seem to result directly from the comparison of the table of analysis of the Feldspars of the Dublin and Wicklow Granite, made by Galbraith, in 1856, with that of the Microclines analyzed by Damour and Pisani, and published in Descloiseaux's Memoir; and this comparison will also help to prove how important is the determination of the physical and optical properties of minerals relatively to the interpretation of their chemical analysis. The comparison of these tables seems, therefore, both interesting and even a necessary compliment to this paper, and I accordingly annex it.

Tables referred to—

Damour and Pisani.

Ann. de Phys. et Chim, Tom. IX., December 1876.

—	I.	II.	III.	IV.	IV. bis.	V.	VI.	VII.	VIII.	IX.	X.	XI.
Silica,	64·30	64·08	64·80	65·75	65·17	65·55	64·97	64·80	65·43	65·43	64·70	64·90
Alumina,	19·70	20·70	19·60	20·90	17·70	20·30	21·47	19·90	19·58	19·58	19·50	20·92
Ferric Oxide,	0·74	–	–	–	0·50	–	–	–	0·35	0·35	–	0·28
Potash,	15·50	13·75	13·50	13·20	13·86	13·90	12·20	12·11	12·45	12·45	12·90	10·95
Soda,	0·48	1·27	1·56	1·60	1·64	1·60	1·78	2·10	2·31	2·31	3·40	3·95
Lime,	–	–	–	–	0·56	–	–	–	–	–	–	–
Magnesia,	–	–	–	–	0·25	–	0·32	–	–	–	–	–
Loss by ignition,	0·35	0·20	0·20	0·20	0·65	–	0·81	0·30	0·30	–	–	0·20
	101·17	100·0	99·66	101·65	100·33	101·41	101·55	99·21	100·12	100·12	100·50	101·80
Sp. Gravities,	2·54	2·55	2·562	2·54	–	2·576	2·47	2 584	2·584	2·543	2·58	2·57

Galbraith.

Journal Geological Society, Dublin, 1856, *p*. 226.

—	Dalkey.	Three Rock.	Lough Bray.	Lough Dan.	Glenmacanass.	Glendalough.	Glen maluro.
Silica, . . .	64·00	65·40	65·44	65·05	64·19	63·60	64·48
Alumina, . .	18·11	17·71	18·36	17·72	18·39	18·84	19·04
Ferric Oxide, .	–	–	–	–	–	–	–
Potash, . . .	12·73	10·68	12·34	13·42	11·39	14·33	10·74
Soda, . . .	3·00	3·26	2·73	2·75	2·95	1·92	2·64
Lime, . . .	trace.	trace.	0·80	0·23	0·70	trace.	trace.
Magnesia, . .	0·57	1·77	–	trace.	0·34	0·40	1·02
Loss by ignition, .	0·55	0·69	0·52	0·36	0·58	0·60	0·78
	98·96	99·51	100·19	99·53	98·54	99·69	98·70
Sp. Gravities, . .	2·54	2·562	2·554	2·559	2·553	2·453	2·560

Taking into consideration the difference of time and general conditions represented by these two series of analyses, it must be admitted that they singularly approach one another, so much so, that it may be assumed, chemically, that the Feldspars analyzed by Galbraith, were Microclines, and characteristic of the granites containing them.

XXIV.—ON SPHEROIDAL JOINTING IN METAMORPHIC ROCKS IN INDIA AND ELSEWHERE, PRODUCING A STRUCTURE RESEMBLING GLACIAL "ROCHES MOUTONNÉES," BY V. BALL, M.A., F.G.S., OF THE GEOLOGICAL SURVEY OF INDIA.

[Read December 15th, 1879.]

Some years ago, when engaged in the geological examination of a portion of Western Bengal, where metamorphic rocks exclusively prevail, I frequently met with zones or narrow tracts wherein a particular form of rock prevailed, which formed rounded boss-like or dome-shaped hills, of a character which I had never encountered elsewhere, and of the origin of which I had not then, as I have not since, met with any published explanation. Since that time I have frequently seen similar and similarly formed hills, not only in various other parts of India, but, quite recently, I have found the same structure occurring in rocks possessing the same lithological characters in Switzerland. It is in consequence of this last observation, and because I believe the structure has in that country not been duly recognised, that I now enumerate the following facts, and venture to account for them by a theory which is, however, as yet, confessedly somewhat imperfect.

The dome-shaped masses in India, which I have alluded to, rise abruptly from the surrounding soil or rocky surface, as the case may be, sometimes singly and sometimes in groups—the individual domes being only occasionally in very close juxtaposition to one another.

At first sight they appear to be perfectly solid masses of rock, with symmetrical rounded or rather ellipsoidal contours. In many, if not in most cases the surfaces are so smooth and steep that under the influence of tropical rains they are incapable of retaining any covering of soil, and consequently, besides a small fern which manages to obtain a footing in cracks and fissures, vegetation is seldom found upon them. The size of these domes varies, but the height rarely exceeds 100 feet, and is generally

less than fifty, while the length of the greater diameter may run to 1,000 feet, or even a quarter of a mile in exceptional cases. It will not be necessary to mention more than two among the various types of contour assumed by these domes; one may be called normal, while the other is a somewhat exceptional conical or sugar-loaf form.

A good idea of the normal forms may be suggested by comparing them to what would be the appearance presented by keel-less ironclad vessels if inverted on land.

Generally the rock of which these domes are composed is a coarsely porphyritic granite,* containing twin crystals of orthoclase felspar from one to two inches long. Sometimes, however, the rock is a fine-grained granite with a large proportion of amorphous, or more correctly, perhaps, not distinctly crystalline felspar.

Occasionally, in the first-mentioned variety, we find the mica either locally or throughout replaced by hornblende, the rock thus assuming the characters of a syenite.

Foliation and bedding structures are not generally present, and from the absence of these and the relations which the rocks bear to the schists and gneisses surrounding them, it might be thought perhaps that they were really intruded masses of plutonic origin. Since, however, in some cases both structures are present, and there is nothing lithologically to distinguish these larger masses from some which occur in thin beds, alternating with ordinary well-defined gneisses and schists, it is probable that they are likewise of metamorphic origin.

It should be added that, in some cases where there is no foliation, properly so called, there is to be observed a general parallelism of the large crystals of felspar.

Although, in the majority of instances, these large spheroidal masses may appear to be solid throughout, it is not long before

* An analysis of a specimen of it is given by the late M. H. Ormsby, LL.D., in a former number of the Journal of this Society. (New Series, Vol., iii., 26.)

Silica, . .	65·04
Alumina, . .	19·60
Lime, . .	0·87
Magnesia, .	2·48
Potash, . .	12·60
	100·61

the observer meets with cases where the upper surface has been broken into, and the fact is then revealed that the domes consist of concentric shells, having a structure similar to that seen on the small scale, for example, in certain iron ores and in urinary calculi.

As is represented, where the outer shell has been broken into by weathering or other causes, its fragments rest upon a smooth surface below. In some cases several successive shells are disclosed, the planes of jointing separating which, preserve a uniform distance from one another throughout, and cut through the crystals of felspar sharply, and at all angles as they follow the curves.

The shells vary in thickness from about three to ten inches, but in any individual dome the thickness appears to be tolerably constant throughout each layer. If what has been above said is sufficiently clear, it will have been understood that the shells rest upon the surfaces of one another successively, like the shells of some nuts on their kernels. Supposing an outer shell to be removed, a perfectly smooth surface, which will soon receive a high polish from atmospheric agencies, is disclosed, and when in this condition the resemblance of the domes to veritable *roches moutonnées* is indeed striking.

Now, what is the origin of this structure? It is unnecessary here to discuss the evidence for or against glacial actions having taken place in India, at a former period of the world's history. Pretty complete evidence of floating ice having deposited its load of stones and mud in the Talchir (Permian ?) period is found in the peninsula; but in the case at present before us, it is manifest that though a glacier is undoubtedly competent to chisel rocks into a dome-shaped contour, it does not possess the power of inducing a concentric shell structure in the mass of a rock.

If other evidence were wanting, the conical shaped hills, which are clearly due to a variety of the same structure, would dispose of the possibility of a glacial origin.

Some local observers in India, struck with the phenomenon, have suggested that the splitting off of the successive shells might be due to sudden shrinkage, caused by showers of rain falling on the rock when highly heated by the sun; but I am not aware that this view has been adopted by anyone having a knowledge either of physics or geology sufficient to enable him

to realize the nature of the phenomena, which it is thought may in this manner be so simply explained. I believe, however, that all who do possess a knowledge of these subjects will agree that such an explanation cannot be seriously entertained with reference to the splitting off of shells of rock averaging six inches in thickness.

Although I am unable to state positively that such is the case, it seems to be highly probable that these domes are really portions of complete spheroidal masses, which have become isolated from their original surroundings by the erosion of softer, more readily decomposable, parts of the rock. On the small scale, in the case of both volcanic and plutonic rocks (basalts and granites), most geologists are familiar with the pseudo-boulders, which are the result of local hardness and the removal of softer more easily decomposed, portions. Such pseudo-boulders frequently have a concentric ex-foliating structure, but this is generally accompanied by much decomposition of the layers and alteration of the mineral components, which is not found to be the case with the shells in the domes, as the rock is always firm and sound, yielding a metallic ring on being struck, or even when *in situ* it is trodden under foot. Its fracture, moreover, is sharp and angular.

On the whole, it seems probable that the spheroidal jointing may have been produced by shrinkage on cooling after crystallization had taken place.*

As I said above, this theory of origin is imperfect, but I venture to think the main object of this paper has been attained, namely: It has been demonstrated that dome-shaped hills and surfaces, resembling *roches moutonnées*, may be produced by a cause other than the action of glaciers. This fact being admitted, I shall now apply it to a locality in Switzerland, where, in the midst of glaciers, the same structure occurs, largely developed, and where, so far as I have been able to refer to authorities, the rounded surfaces are described as being produced by glaciers, without any suggestion as to the possibility of the form being in part due to other causes.

When crossing the Grimsel Pass last October, I first met in

* Another explanation has been suggested by the Rev. Professor Haughton, in reference to the Swiss rocks, namely, that these planes may be due to a form of cleavage produced under great pressure during upheaval of the mountain ranges.

Switzerland gneiss-rock of similar porphyritic character to that which I have above described. In the neighbourhood of the Todten-see, to the east of the sources of the Unter-Aar-Glacier, and between it and the Grimsel Hospice, and again below the Handeck, on the road to Guttannen, there are extensive rounded surfaces, which, in many cases, proved on examination to be precisely similar in character to those above described in India. There was the same concentric shell structure, and, in places where the outer layers were broken into, there were to be seen disclosed underneath new surfaces, which only required the action of rain and the fan-like streams which spread over these rounded slopes to produce a high degree of polish. Owing to the fact that, at the time when I crossed, the weather was foggy and threatening, and a foot or so of fresh snow lay on the ground, my examination was hurried and incomplete, and I am unable to be more exactly specific in my references, but of this I am fully satisfied, that while minor tracks of glaciers, such as striæ, and possibly true *roches moutonnées* do occur in this neighbourhood, the major features are not due to glaciers, but are to be attributed to the concentric shell structure of the rock itself.

In none of the authorities to whose writings I have been able to refer can I find any hint of this, but, on the contrary, the rounded slopes are referred to as a proof of the former extent and size of the glaciers. Thus, Mr. J. Ball, in his Alpine Guide,* has written:—

"The geologist will observe with interest the traces of glacial action that are not only apparent in the neighbourhood of the Hospice and on the rocks surrounding the lakes, but even up to and above the summit of the Pass, indicating by the direction of the furrows that the vast mass of ice that once filled the head of the Valley of Hasli must have flowed over the Grimsel Pass towards the Valais. Neither will he fail to remark the contrast between the rough and jagged outlines of the upper ridges, that have never undergone the planing action of the glacier, with the condition of those parts which lay below the level of the ancient ice streams."

Here there is no recognition of the existence of any innate structure to account for the rounded outlines, all being set down as the work of ancient glaciers.

I believe it possible that some of the "domes arrondis polis et

* Central Alps, 1866, p. 81.

striés au dessus de la Handeck," figured by Agassiz in his classic work on glaciers, may owe their form in part to this structure, which seems to be almost a proper characteristic of this form of granitic gneiss wherever it occurs. But in making this last suggestion, I do so with some hesitation, as I am not sure of the exact locality of the particular domes referred to.

Baedeker,* too, speaks of the granite rocks in this area being rounded and polished by glacier friction.

It would probably be easy to multiply such references, but I have not yet succeeded in finding any allusion to the concentric shell structure of the gneiss itself as being, to say the least, an important factor in the production of the surfaces which have attracted so much notice on the northern slopes of the Grimsel.

* Guide to Switzerland.

NOTE ADDED IN THE PRESS. I am indebted to Professor O'Reilly for calling my attention to Professor Whitney's Geology of California, where in the description of the Sierra Nevada, domes of precisely similar character to those in India are alluded to, and regarding which Professor Whitney remarks, "That this structure is not the result of the original stratification of the rock is evident from a study of the phenomena, which do not indicate anything like anticlinal or synclinal axes, or any irregular folding. The curves are arranged strictly with reference to the surface of the masses of rock, showing clearly that they must have been produced by the contraction of the material while cooling or solidifying." His explanation of the structure, therefore, is identical with mine—near the San Joaquin a remarkable dome which rises to the height of 1,800 feet "presents exactly the appearance of the upper part of a sphere, or as Professor Brewer says, of the top of a gigantic balloon struggling to get up through the rock." The same description, except as regards the height, might be applied to many of the domes which I have seen in India.

XXV.—ON ROSSETTI'S LAW OF COOLING, APPLIED TO THE CONSIDERATION OF THE RELATIVE EFFECTS OF SUN-HEAT, EARTH-HEAT, STAR-HEAT, AND ATMOSPHERIC CONDITIONS UPON CLIMATES DURING GEOLOGICAL TIME, BY REV. SAMUEL HAUGHTON, M.D., D.C.L., F.R.S.

[Read January 19th, 1880.]

NEWTON'S famous law of cooling assumed that the radiation was proportional to the difference between the temperature of the body cooling and the temperature of the inclosure.

If θ, Θ denote these two temperatures, and t denote the time, Newton's law is—

$$\frac{d\theta}{dt}=k\,(\theta-\Theta). \tag{1}$$

This gives, by integration,—

$$t=\frac{1}{\mathrm{K}}\log_e(\theta-\Theta)+\mathrm{C}. \tag{2}$$

where K and C are unknown constants.

This law holds true as long as the difference of temperatures, $\theta-\Theta$, is not large, but fails entirely when it is great.

Under these circumstances a new law of cooling was proposed by Dulong and Petit, which, although artificial in its conception, and deviating from the simple idea of the Newtonian law nevertheless was found to represent observations better than the Newtonian law, when the difference of temperatures became greater.

According to this law—

$$\frac{d\theta}{dt}=\mathrm{A}\,(\mu^{\theta}-\mu^{\Theta}) \tag{3}$$

where $\mu=1{\cdot}0077$ for all bodies, and A depends on the nature of the cooling body.

This relation gives, after some deductions, by integration, the following:—

$$t=\mathrm{K}\log\left(\frac{\mu^{\theta-\Theta}-1}{\mu^{\theta-\Theta}}\right)+\mathrm{C}. \tag{4}$$

where K and C are unknown constants.

Dulong and Petit's law of cooling fails, as Newton's did, when

the difference in temperature between the cooling body and its inclosure becomes large.

The most recent advance made in this subject is the important discovery, made by Mr. Rossetti, that Newton's law of cooling becomes accurate for great ranges of temperature, provided we make the coefficient K a function of the *absolute* temperature of the cooling body, instead of being a constant; and this function turns out to be nearly proportional to the square of the *absolute* temperature.

Newton's law thus becomes—

$$\frac{d\theta}{dt} = (\theta - \Theta)\ (\alpha\, T^2 - \beta). \qquad (5)$$

where T is the *absolute* temperature, and β is a very small constant as compared with α.

In order to apply Rossetti's law of cooling to the case of the earth's surface, I suppose a to be the temperature of the layers of upper atmosphere which controls the radiation of heat from the earth's surface; a being regarded as positive when below zero.

We now have (neglecting β)—

$$\begin{aligned} \theta - \Theta &= \theta + a \\ T &= 460 + \theta \\ \beta &= 0 \end{aligned}$$

and, finally,—

$$\frac{d\theta}{dt} = \alpha(\theta + a)\ (460 + \theta)^2. \qquad (6)$$

This gives by integration, after some reductions, and writing A for 460—

$$t = \frac{1}{\alpha\,(A - a)^2}\left\{ \log\left(\frac{\theta + a}{\theta + A}\right) - \left(\frac{\theta + a}{\theta + A}\right) \right\} + C. \qquad (7)$$

The following Table gives the annual sun-heat and mean annual temperatures of the Northern Hemisphere:—

Sun-heat.	Mean Temperature.	Latitude.
41·9 feet of ice,	4·5° F.	80°
46·3 "	14·4 "	70
55·7 "	29·3 "	60
66·8 "	43·4 "	50
77·3 "	56·5 "	40
85·9 "	67·6 "	30
92·4 "	77·6 "	20
96·5 "	81·0 "	10
97·8 "	80·1 "	0

From each of these we obtain, by Rossetti's law (6), an equation, viz.—

$$S = a\,(\theta + \alpha)\,(\theta + 460)^2. \qquad (8)$$

where S is the sun-heat, and θ the mean temperature.

The values of α and a, deduced from these equations, taken in pairs, are—

	Lat	α	a
(1.)	80° / 70	160·5° F.	$\frac{0{\cdot}2489}{(460)^2}$
(2.)	70 / 60	100·2 „	$\frac{0{\cdot}3801}{(460)^2}$
(3.)	60 / 50	76·7 „	$\frac{0{\cdot}4644}{(460)}$
(4.)	50 / 40	89·1 „	$\frac{0{\cdot}4210}{(460)^2}$
(5.)	40 / 30 *	114·3 „	$\frac{0{\cdot}3590}{(460)^2}$
	Mean,	108·16° F.	$\frac{0{\cdot}3747}{(460)^2} = \frac{1}{564{,}718}$

This result would indicate for the temperature of the "inclosure" of upper atmosphere that controls the radiation of heat at the earth's surface, 108·16° F. below zero.

Frölich,† who has recently made important researches on this subject, with greatly improved and delicate instruments, at St. Petersburgh, has found a similar quantity, called by him *Himmelstemperatur* (Sky-temperature), which varies considerably from month to month and from night to night. Thus he found for the sky-temperature of the zenith, in 1876—

20th October,	123·70° F. below zero.	
21st „	119·29	„
23rd „	93·19	„
14th August,	38·29	„
15th „	39·00	„
17th „	49·09	„
14th October,	34·33	„

* The latitudes below 30° give less reliable results, because the differences from which α and a are calculated are too small.

† Repertorium für Meteorologie, vol. vi., part i., (p. 1). (St. Petersburgh, 1876.)

The corresponding results for the Southern Hemisphere are—

Sun-heat.	Mean Temperature.	Latitude.
55·7 feet of ice,	35·3° F.	60°
66·8 „	47·8 „	50
77·3 „	57·9 „	40
85·9 „	66·7 „	30
92·4 „	74·7 „	20
96·5 „	78·7 „	10
97·8 „	80·1 „	0

From these data we obtain, by Rossetti's law,—

	Latitude.	a.
(1.)	60°, 50	54·0° F.
(2.)	50, 40	40·2 „
(3.)	40, 30	60·3 „
(4.)	30, 20	51·0 „
(5.)	20, 10	77·5 „
(6.)	10, 0	90·3 „
	Mean,	62·217° F.

From this it follows that the mean "*sky-temperature*," which controls the radiation of heat from the surface of the earth, is higher in the Southern Hemisphere than in the Northern; so that the Southern Hemisphere retains more of the heat received from the sun than the Northern Hemisphere* does.

The *sky-temperature* of Frölich corresponds with the *temperature zenithale* of Pouillet, which is the exact equivalent of the joint action of the atmosphere and of space upon the thermometer.

Both Pouillet and Frölich have attempted to separate the variable effect of the atmosphere from the constant effect of space, and Pouillet finds for the temperature of space (−142° C)= −223·6 F Frölich finds for the temperature of space (*Weltraums-temperatur*), by St. Petersburgh observations, 17th August and 23rd October, −131° C and −127° C, the mean of which gives −202·2° F.

* This is due to greater water-surface, and consequently greater amount of aqueous vapour in the air.

The mean result of Pouillet and Frölich is—

Temperature of Space, $= -212{\cdot}9°$ F.

The term *temperature of space* requires definition, for in one sense it is absurd, because we do not believe in any material particles existing in interstellar, or even in interplanetary space, capable of receiving and emitting heat. I think that the term *star-heat* expresses better what we really mean by the temperature of space.

Notwithstanding the high authority of Pouillet, and his ingenious attempts to defend his result, there exists a very general scepticism on the subject.*

If Pouillet had used the term *star-heat,* he would have been astonished at his own result, viz., that the mean annual heat received by the earth from the sun would melt a sheet of ice-covering equal to 101·7 feet; while in the same time the space-temperature, or star-heat, would melt an ice-covering equal to 85·3 feet!

Inside any planetary system, the central star or sun must be the chief source of heat, and the effect of the remote stars not appreciable; and in the space midway between any two stars or suns, the temperature of a body, if placed there, must fall to the absolute cold, or 460° F. below zero.†

In order to discuss the question of geological climates, let us return to the equation (8), or

$$H = \alpha\,(\theta + a)\,(\theta + A)^2. \qquad (9)$$

in which H denotes the annual heat received and radiated; α, a coefficient depending upon the radiating surface; a, the temperature of the "*heat-inclosure*," including space-radiation, and the "convection" and "conduction" of the atmosphere; θ, the mean annual temperature of the place of observation; and $A = 460°$ below zero of Fahrenheit, or the temperature of absolute cold.

* Pouillet observes that to us the sun occupies only five-millionths of the celestial vault, whereas the *space-temperature*, or rather *star-heat*, acts over the whole vault. To this it may fairly be replied, that as the visible stars appear to us as mere points, the whole of them put together would not form the sun's disc, and that they are indefinitely farther off.

† Derived from the well-known relation between pressure, volume, and temperature of gases, which in Fahrenheit units, gives the equation;

$$\frac{vp}{460+\theta} = \frac{v'p'}{460+\theta'}$$

Between 80° N. lat. and 70° N. lat., at present;

$$\alpha = \frac{0 \cdot 2489}{(460)^2}$$

$$a = 160 \cdot 5^\circ \text{ F below zero.}$$

$$A = 460^\circ \text{ F} \quad ,, \quad ,,$$

In former times, Miocene, Jurassic, and when albumen coagulated, we have H, the heat supplied and radiated annually, depending on four quantities, viz.:—

1st. Sun-heat.

2nd. Earth-heat.

3rd. Thermal properties of the earth's atmosphere.

4th. Star-heat.

Of these four quantities, the fourth only, or star-heat, is known; for we may safely assume that, during geological time, the earth and solar system were as far removed as they are now from the influence of any star except that of the sun itself, and that the heat derived from stars was always of no account.

As we cannot separate the effect (in geological times) of the influence of the sun, earth, and atmosphere, I shall consider the following three cases, from which, as I believe, much instruction may be derived—

(A.) The *sun*, as the sole source of heat, the earth and atmosphere conditions being as at present.

(B.) The *earth*, as the sole source of heat, the sun and atmosphere conditions being as at present.

(C.) The thermal properties of the earth's atmosphere being varied, while the sun-heat and earth-heat remain as at present.

(A.)—*Sun-heat regarded as the sole cause of changes in Geological Climates.*

In this case we have—

$$H = \alpha\,(\theta + a)\,(\theta + A)^2. \qquad (9)$$

where α, a, A, have the values just given, and at 80° N. lat.

$\theta =$	4·5° F., .	Present time.
θ* $=$	44·3 ,, .	Miocene time.
$\theta =$	68·7 ,, .	Jurassic time.
$\theta =$	122·0 ,, .	Coagulation of albumen.

* By interpolation, for at Disco, 70° N. lat., $\theta = 55 \cdot 6^\circ$ F., and at Grinnell Land, 81° 44′ N. lat., $\theta = 42 \cdot 3^\circ$ F.

Substituting in equation (9), we find—

H= 41·90 feet of ice,	.	. Present.
H= 61·26 ,,	.	. Miocene.
H= 75·36 ,,	.	. Jurassic.
H=112·56 ,,	.	. Albumen coagulation.

or as follows :—

Comparative Table of Sun-heats at 80° *N. lat. at various Geological Periods.*

(1.)	Present time, . . .	100·00
(2.)	Miocene time, . . .	146·20
(3.)	Jurassic time, . . .	179·85
(4.)	Time of coagulation of albumen,	268·60

When we consider that the whole of geological time is as insignificant in comparison with astronomical time, as the human period is in comparison with geological time; and that in astronomical time the sun-heat has been reduced to many thousandths of its original value; it will not appear a great effort of the imagination to explain the phenomena of geological climates by the hypothesis of a sun which has cooled down, during geological time, to about one-third of what its value was when life began to appear.

We may approximate to the relative durations of Geological periods, by calculating the times of cooling of the sun, to the amounts represented in the foregoing table. Properly speaking this should be done by a formula similar to (9) in which a would denote the "heat-inclosure" of the sun, and α a coefficient depending on the properties of the sun's surface, both of which quantities are completely unknown.

We may, however, obtain an approximate result by calculating the times of cooling of the sun, on the supposition that it radiates directly into space, neglecting the influence of the solar atmosphere.

This supposition reduces equation (8) to the following—

$$-\frac{d\theta^*}{dt} = \alpha\,(\theta + \mathrm{A})^3 \qquad (10)$$

* We use the negative sign, because as t increases θ diminishes.

This gives, by integration,

$$t - t' = \frac{1}{a}\left(\frac{1}{(\theta + A)^2} - \frac{1}{(\theta' + A)^2}\right) \qquad (11)$$

From this equation, we find, substituting the proper values (as above given for θ, a, θ') the following relative lengths of time—

1°. Present time to Miocene time . . .	41·7
2°. Miocene time to Jurassic time . . .	21·1
3°. Jurassic time to time of albumen coagulation	37·2
	100·0

These numbers are written down to the scale, on which 100 represents the whole duration of organic life, from the present time to the time of coagulation of albumen at 80° N. Lat.

From the foregoing results the following conclusion may be deduced—

That the time elapsed from Miocene times to the present time, is 41·7 per cent. of the whole time of the existence of life on the globe.

(B.) *Earth-Heat regarded as the sole cause of changes in Geological climates.*

It is easy to show that Earth-heat has been always, probably not a very important factor in Geological climates. We may demonstrate this statement as follows—It has been just shown, that if atmospheric conditions were the same as at present, the quantities of heat, at 80° N. lat., required to keep up the necessary radiation, at various Geological times, would be—

Present time . .	41·90	melted feet	of ice.
Miocene time . .	61·26	„	„
Jurassic time . .	75·36	„	„
Albumen coagulation time .	112·56	„	„

and I have already calculated the amounts of increase of sun-heat, sufficient to account for the several climates.

If the sun-heat had been the same as at present, we have to provide heat from some other source (say earth-heat) to account

for the following excess of radiation above the present radiation at 80° N. lat.

Miocene times . .	19·36 melted feet of ice.
Jurassic times . .	33·46 " "
Albumen-coagulation .	70·66 " "

Let us suppose the earth to be a globe of boiling water, and calculate how long she could keep up the foregoing radiations, before being converted into a globe of ice.

Imagine a cone with its vertex at the centre of the earth, and its base, a square foot, at 80° N. lat.; the volume of this cone will be, in cubic feet—

$$\frac{4000 \times 5280}{3} q.p.$$

Let e be the excess of heat radiated at any geological time, above that radiated at present in the same latitude; and let n be the number of years before the cone of boiling water is converted into a cone of ice; we now have, since the difference between the boiling and freezing points is 180° F. and since the latent heat of water is 143° F.—

$$143\, e\, n = \frac{4000 \times 5280 \times 323}{3}$$

or

$$n = \frac{4000 \times 5280 \times 323}{3 \times 143 \times e}. \tag{12}$$

From (12) we calculate—

Lengths of time required to convert the cone of boiling water into the cone of ice at 80° N. lat., at the rates of radiation corresponding to

1 Miocene time . . .	821,360 years.
2 Jurassic time . . .	475,240 "
3 Albumen-coagulation . .	225,040 "

If we assume, as an approximation to the relative durations of geological times, the numbers given at p. 8, and make use of the mean of the radiations at the beginning and end of each period, we shall find, for the mean radiation at 80° N. lat. during

the entire duration of geological time, the following equation; *Mean radiation of heat at 80° N. lat. in excess of present radiation*—

$$=\frac{19\cdot 36 \times 41\cdot 7}{200}+\frac{26\cdot 41 \times 21\cdot 1}{200}+\frac{52\cdot 06 \times 37\cdot 2}{200}$$

$$=28\cdot 988 \text{ feet of ice.}$$

From this we calculate the entire duration of geological time, considered as dependent on the heat of the earth alone, by means of equation (12) to be 548,540 years; or somewhat over half a million of years. But, in reality, the duration of geological time, could not have been nearly so great as this, if the earth were the sole source of heat, for in the foregoing we have supposed the heat given freely to the surface from the interior, as if the conductivity of the earth were infinite. In reality the heat would be transmitted slowly to the surface, which latter would cool rapidly, making geological time very short, although a large store of heat might remain in the central parts of the earth, though not available to mitigate sensibly the rigour of the surface climate.

It is highly probable that the earth cooled down to a condition in which the central heat had but little effect upon climate, long before the commencement of geological time; so that climates always depended, chiefly, on sun-heat, modified by atmospheric conditions.

Let us now consider the influence of the latter—

(C.) *Atmospheric conditions considered as the sole cause of Geological Climates, the Sun-heat and Earth-heat being the same as at present.*

In the equation (9), or

$$=\alpha(\theta+a)\,H\,(\theta+\mathrm{A})^2 \qquad (9)$$

α is a coefficient independent of temperature, depending on the surface conditions of the place of observation.

a, or the control temperature of the inclosure, depends on the atmosphere and on star-heat; or on atmospheric conditions only if star-heat remained as now through all geological time.

H depends of sun-heat and earth-heat only.

At present, at 80° N. lat., we have

$$H=41\cdot9 \text{ feet of ice.}$$
$$\theta=4\cdot5° \text{ F.}$$
$$a=\frac{0\cdot2489}{(460)^2}$$
$$a=160\cdot5° \text{ F.}$$

In Miocene times

$$H=41\cdot9 \text{ (by hypothesis)}$$
$$\theta=44\cdot3°$$
$$a=\frac{0\cdot2489}{(460)^2}(?)$$

From these data, we find by equation (9), the value of a in Miocene times

$$a=95\cdot76° \text{ F}$$

In like manner, we find the value of a, corresponding with $\theta=68\cdot7°$ F (Jurassic), and $\theta=122\cdot0°$ F. (albumen coagulation); and finally,

The temperature of the Heat-inclosure, depending on atmospheric conditions, necessary to produce the requisite Geological Climates, independent of any increase of Sun-heat or Earth-heat at 80° N. lat.

	a.
Present time . . .	+160·50° F.
Miocene ,, . . .	+ 95·76 ,,
Jurassic ,, . . .	+ 58·73 ,,
Albumen-coagulation time . .	− 16·84 ,,

The positive values are reckoned below zero of Fahrenheit, and the negative values are reckoned above zero.

It is very unlikely, that the thermal constants of the earth's atmosphere have ever changed so much as to convert an inclosure of 160·5° below zero into an inclosure of 16·84° above zero, through 177·34° F. altogether; nevertheless, it is quite certain that conditions formerly existed in the earth's atmosphere which operated in the direction here indicated, and which may have greatly economised the increase of sun-heat required, without accounting for the entire change in climate.

Professor Tyndall* has given the following relative absorptive power for heat emanating from a source at 212° F. of various gases at the normal pressure of 30 inches, when a column of the gas, 4 feet in length was subjected to experiment.

* Miller's Elements of Chemistry, part i., pages 338–9.

Absorptive power of gases for non-luminous heat.

1. Air	1	8. Carbonic acid	90
2. Oxygen	1	9. Nitrous oxide	355
3. Nitrogen	1	10. Sulphuretted hydrogen	390
4. Hydrogen	1	11. Marsh gas	403
5. Chlorine	39	12. Sulphurous acid	710
6. Hydrochloric acid	62	13. Olefiant gas	970
7. Carbonic oxide	90	14. Ammonia	1195

The experiments of Tyndall also establish the fact that aqueous vapour has a powerful absorbent action upon heat of low refrangibility; varying from 30 times to 70 times the effect of pure dry air.

It is quite certain that in Palæozoic times, the atmosphere contained a very large proportion of carbonic acid, which has since disappeared; and it is the opinion of many geologists, that as late as Miocene times, there was much more aqueous vapour in the atmosphere than at present. Both of these conditions, one certain, and the other probable, would increase the effect of the atmosphere, regarded as a blanket, to keep in the sun-heat received;—for we must observe that while carbonic acid and aqueous vapour would produce but little reduction in the amount of *luminous* sun-heat received, as compared with pure, dry, air; they would present a formidable obstacle to *non-luminous* heat escaping by radiation from the earth's surface into the cold of star-space.

On the whole, the following appear to me to be the most probable conclusions at which we can arrive as to the causes of former geological climates:—

1st. We must reject any solution based upon a change of position, either in space or within the earth's body, of the axis of rotation, within the limits of geological time.

2nd. We must reject any solution based upon the secular cooling of the earth (with a fixed axis of rotation), regarded as the sole and immediate cause of the change of climate.

3rd. The chief factor in changes of geological climate appears to have been the slow secular cooling of the sun, in consequence of which the earth's surface cooled gradually down.*

* A hot body placed in a cold space would cool down, as the schoolmen would say, *immediately*; but a body deriving its heat from a cooling fire, would cool down *mediately*. The earth has done both, but its chief cause of cooling has been the diminishing heat of the sun.

4th. During Palæozoic times the amount of sun-heat required to keep up the known surface-temperatures was *certainly* less than I have calculated from No. 3, because of the large quantity of carbonic acid then forming a part of the atmosphere.

5th. During Neozoic times the amount of sun-heat required to keep up the known surface-temperatures was *probably* less than I have calculated from No. 3, in consequence of the large quantity of aqueous vapour then existing in the atmosphere as compared with the present time.

6th. The so-called Pluvial period and Glacial period were probably the result of atmospheric changes caused by a temporarily diminished rate of heat-radiation from the sun, causing a precipitation of aqueous vapour, followed by an increased radiation of non-luminous heat into space from the surface of the earth.

XXVI.—ANNIVERSARY ADDRESS TO THE ROYAL GEOLOGICAL SOCIETY OF IRELAND, BY G. H. KINAHAN, M.R.I.A., President.

[Read February 16th, 1880.]

THE past year has been one of considerable activity in our Society; but I do not propose to give now a *resumé* of our proceedings. I cannot, however, pass, without mention, the fact that, in accordance with the proposal that an annual geological excursion should form part of the programme of the Society, such an excursion was organized last summer to Ovoca, a very eligible geological locality. It was attended by a goodly number of Fellows and their friends, including several ladies, and, with the exception of a slight temporary interference on the part of the weather, everything passed off well, and apparently to the satisfaction of all the company.

Instead, then, of giving, in this Anniversary Address, a review of the papers read before the Society during the last twelve months, I would direct the attention of Fellows to the following subject of general interest to geologists, viz.:—The system, which is at present too prevalent, of estimating the Thicknesses of Geological Formations.

To estimate, with approximate correctness, the thickness of a formation, is often, and in various ways which need not be pointed out, a very important problem in geology; and, if it is wrongly done, serious ulterior error may be the result. It seems to me to be frequently the case, at present, that incorrect conclusions are drawn respecting this matter, and that the different groups or formations are usually made to appear of greater than their true thicknesses.

The presentations of a formation in different districts are too often taken as if they were similar to different copies of the same book; and if some sub-group which appears in one place is not present in another, its absence in the latter is regarded as a hiatus which ought to be filled up with a supposititious group of

strata, in order to produce correspondence with what is seen in other places.

In the progress of geology, as facts accumulated, it was found that the strata forming the crust of the earth were capable of being divided into groups distinguishable from one another by special characters; and such groups are now known as "formations." Formations are distinguished from each other both stratigraphically and palæontologically. Stratigraphically, a typical formation, as a general rule, has its beginning and ending distinctly marked; the beds belonging to it lying unconformably on those of the older formations, while those of the succeeding ones lie unconformably on its strata. However, there are cases in which the rocks of one formation have "passage-beds" into those above or below them, but such cases are exceptional.

A formation consists of a greater or less number of sub-groups of strata which have certain general characters common to all. These sub-groups are often distinct from each other, but usually each sub-group graduates into those above and below. Nearly always one or more of the sub-groups, which in the entire make up a formation, are in some places better developed than the others; or, as is often the case, peculiar groups may appear exceptionally in certain limited areas and not elsewhere; and some sub-groups, which are always traceable in certain regions or countries, may be exceptionally absent in others. These changes have often been misinterpreted, and some of the geologists of the present day go on the supposition that a formation is incomplete in some particular district unless all the sub-groups which can be seen anywhere else are present; also that the absence of any one in a certain area is to be necessarily regarded as a hiatus in the series, and evidence of a period of time during which no strata were deposited (this last conclusion is, of course, occasionally correct). In estimating the whole thickness of the formation, they therefore include not only the rocks which are present, but also those which they suppose to be wanting; thus often making the whole thickness much greater than it may really be.

Such a mode of calculation is, I believe, as a general rule, erroneous. The ancient strata were accumulated in more or less distinct basins, or what comes practically to the same effect, as

regards the present question, in the vicinity of more or less distinct sources of material, similarly to what is going on at the present day. The fact of the accumulation in more or less separate basins of the materials of various formations has been contended for by Dr. A. C. Ramsay, and more recently it has been prominently brought forward by Dr. Archibald Geikie, in his paper on the "Old Red Sandstone of Western Europe."* From my own observations in Ireland I have been gradually led to a similar conclusion respecting each of the Irish rock-formations. These, from the Cambrian to the Miocene, apparently consist of somewhat separate basin-accumulations; and the real thickness of the groups seems to be less than what is usually supposed.

In many cases, no doubt, it is unwarrantable to argue from small to great things; but in that which I am now considering, this is not so; in it the difference of scale cannot affect the principles involved, nor the mode of the operations. If, then, in legitimate illustration of the present point, we examine a recent lake-accumulation, we often find in one part shingle, in another gravel or sand, elsewhere marl or clay, or perhaps peat; and if circumstances allow a section to be cut across the deposits, the shingle, gravel, and sands will nearly always be found dipping at greater or less angles, the clays and peat being more or less nearly horizontal, while the marl may have different characters in different places, according as it has been mechanically or chemically formed.

If the thickness of the accumulation, as a whole, is calculated by adding together those of all the layers of different composition, a much greater thickness will often be arrived at than that which would be possible, even if the depth of the whole lake were greater than its present maximum. I have seen a small lake basin, the accumulations of which would, if thus treated, give a thickness of over 100 feet, although in no place was the original lake more than 20 feet deep. In large lake basins the results would probably be much more striking.

If from lake basin deposits we go to those accumulating at the present time in the Atlantic Ocean, we also find deposits of shingle, gravel, sand, clays, peat, &c., going on in different places;

* Trans. Roy. Soc. Edinb., vol. xxviii.

but no one deposit is universal, each extends only over a certain area, sometimes an unexpectedly limited one.

If, in the Atlantic Ocean basin, we followed the mode of calculation now being deprecated, we should arrive at vast thicknesses of strata that cannot possibly be correct. The different deposits now being laid down in the Atlantic, although often strikingly different, and sometimes even definitely limited, are contemporaneous accumulations, whether they adjoin each other or are separated by thousands of miles, and *that*, though one may be shingle, another gravel, or sand, or clay, or limestone, or peat, and also though some are very thick and others extremely thin. Yet, if these strata were to be elevated into land, it is probable we should be asked to believe in numerous intervals of interrupted deposition, because the accumulations of different materials are not all found everywhere present.

In illustration of what has been said I may refer to the Silurian rocks of the United Kingdom, dwelling more particularly on those in Ireland with which I am best acquainted. Under the term SILURIAN, I include the rocks usually called "Upper Silurians" and "Lower Old Red Sandstone."

In former times geologists called certain rocks "Red Sandstone," solely from their colour and lithological character, but it was soon found out that some of these rocks were evidently much newer than the others; these were called "New Red Sandstone," the rest "Old Red Sandstone." Subsequent research gradually proved that some of the arenaceous rocks included in the latter belonged to the Laurentian (?), Cambrian, Cambro-Silurian, Silurian, and Carboniferous systems, and by degrees all these were taken away from that formation, leaving those still called Old Red Sandstone, but which, as I believe, really belong to the Silurian and Carboniferous series; these most English geologists appear to believe constitute a formation in themselves, though a few divide them into *Upper* or *Carboniferous Old Red Sandstone*, and *Lower* or *Silurian Old Red Sandstone.*

The "Lower Old Red Sandstone," and the associated rocks that have in them characteristic Silurian fossils, are those which I have already called Silurians, and it is to these that I shall now refer.

In Geikie's paper, already mentioned, it is shown that in Great

Britain and Ireland the *Lower Old Red Sandstone** occupies distinct basins in which "come local and often peculiar features, whereby even contiguous tracts are distinguished from each other. It is still possible roughly to make out, with more or less clearness, the limits of these basins, which seem sometimes to have been connected by narrows or shallows, and doubtless by occasionally closed water channels; in other cases to have been completely isolated." Prior to Geikie's researches it was generally believed that the entire Old Red Sandstone of Scotland represented three distinct groups, but he believes that his work in the centre and south of Scotland proves the Old Red Sandstone (Carboniferous and Silurian) to consist of only two divisions; the upper portion passing conformably upwards into the Carboniferous formation, while the rocks formerly supposed to form two groups (Middle and Lower Old Red Sandstone) pass conformably downwards into the Silurians. He seems also to believe, that although the lower rocks in the different areas vary both lithologically and palæontologically, yet, chronologically they correspond, all having been deposited at the same time, but in different seas and under different circumstances.

In England the Silurian rocks present somewhat similar aspects, in some places partaking of the characters of the "Upper Silurian," and in others of the "Lower Old Red Sandstone." In South-west England, as in South-west Ireland, rocks of Carboniferous and Silurian types are intermingled. These have not been as yet satisfactorily worked out; but as Geikie, Woodward, and other eminent petrologists, following in the steps of Jukes, are engaged in the investigation of them, we may expect that, before long, their proper chronological position will be established.

In Ireland, although the fossil characters of the Scottish "Lower Old Red Sandstone" do not appear, yet we there obtain important and instructive facts. There are in this country two areas of deposition occupied by these rocks. The most northern is the western continuation of the rocks found in the central

* I am not aware that Dr. Geikie ignores the *Old Red Sandstone* as a formation, as this does not appear in his paper. Whether he will eventually do so or not has still to be seen; he, however, distinctly states that in Scotland the "Lower Old Red Sandstone" is conformable to the underlying Silurian strata.

valley of Scotland,* and the southern is the western continuation of the rocks in Wales and S.W. England.† The northern basin extends from Scotland into the province of Ulster, and from that, through Connaught, into the Atlantic. In N.E. Ulster, on account of the covering of Mesozoic and Cainozoic rocks, the Silurians only appear in one place, as conglomerates lying on Metamorphic rocks (Cambro-Silurians or Cambrians), near Cushendun, county Antrim; but in S.W. Ulster and in the adjoining portions of Connaught they appear more extensively. Here they are principally of "Lower Old Red Sandstone" types; but near Drumshambo, county Leitrim, and on the N.W. of Ballaghaderreen, county Mayo, there are green rocks of "Upper Silurian" types; while in the latter locality fossils not only of English "Upper Silurian" species, but also of "Lower Silurian" species, have been found. Farther westward—north, south, east, and west of Clew Bay—there occurs a detached portion of these Silurians, all of the "Lower Old Red Sandstone" type. In this portion of the basin of deposit no sudden change has been observed; for the most part the rocks are principally arenaceous, often conglomeratic; the argillaceous rocks predominating to the west, in Clare Island and Louisburgh, west and south of Clew Bay. The rocks near Drumshambo and N.W. of Ballaghaderreen are a little more argillaceous than those with which they are associated; but the principal difference between them is in their colour.

But south of the western portion of these rocks, in the country north and south of Killary Harbour, and extending eastward to Loughs Mask and Corrib, rapid and remarkable changes take place in the accumulations, as here is found not only an intermingling of the rocks of the two types, but also zones containing fossil species characteristic of the Caradoc-Bala or English "Lower Silurian"; while the characteristic fossils of the highest group of strata (*Salrock Slates*) is pronounced by Davidson to be of an Upper Llandovery type, although in the rocks below it they are of Wenlock and Ludlow species.

If an attempt is made to calculate the age of these rocks palæontologically, according to the laws laid down in England, we are immediately puzzled, as the Irish palæontological evidence is

* Geikie's "Lake Caledonia Basin."

† Geikie's "Welsh Lake Basin."

conflicting. Stratigraphically, the rocks north of the Killary, at Creggaunbaun, those south of the Killary, at Gowlaun, and those to the eastward, at Kilbride, on Lough Mask, and adjoining the north shore of Lough Corrib, seem to be the oldest; while the rocks elsewhere, although lithologically and palæontologically different, nevertheless correspond chronologically, their different characters and fossils being solely due to the different circumstances under which they accumulated.

If we attempt to calculate their thicknesses in the style so frequently followed, errors will be innumerable. The maximum thickness, from stratigraphical evidence, occurs in N.W. Galway, south-west of Killary Bay; but, from palæontological evidence, the oldest rocks of this area ought to be of the same age as the rocks in the second group at Ballaghaderreen, county Mayo—rocks which, stratigraphically, must be on or nearly at the horizon of the Salrock Beds, that is, the highest group of Silurians in N.W. Galway.

Calculating the thickness of these rocks by their bedding, also similarly misleads, especially in the Toormakeady district, as there the conglomerates have a general westerly dip, and are apparently of great thickness; but the Formnamore Mountain rocks, which seem to be above them, lie nearly directly on the continuation of the eurites, which underlie the Toormakeady conglomerates; thus showing that the Toormakeady conglomerates and the rocks of the Formnamore Mountains are contemporaneous accumulations; their difference in character being solely due to the different circumstances under which they were deposited.

In South-west Ireland (Waterford, Cork, and Kerry) is the Irish portion of Geikie's "Welsh Lake Basin." Here, as in Devonshire and the adjoining portions of England and Wales, there are remarkable and rapid changes, both lithological and palæontological. As, however, it is probable that the rocks of this country will be the subject of papers brought before the Society during the present year, I shall not now enter into the discussion of them.

A study of the Irish Mesozoic rocks, and a comparison between them and those of England and the Continent, gives interesting results. These rocks occupy only a limited area in Ireland, and are confined to the province of Ulster. They are of inconsiderable thickness, and form a continuous *unbroken* sequence from the

Permian up into the Jurassic. In the following table the first column gives the maximum thicknesses of the rocks of Ireland, and the second and third of England and the Continent. For the classification of the English and foreign rocks I am indebted to Professor Lebour, of the Durham University.

Irish.	*English.*	*Continental.*
4. JURASSIC. Lias.	Oolite, 2,500 ft. (J. B. Jordan.) Lias, 1,400 ft. ,, Lr. Lias, 600 to 900 ft. (Lyell.)	Belgium. Upper Lias, 50 to 100 ft. (Dewalque.) Middle ,, 400 to 460 ft. (Dewalque.) Lower ,, 300 to 450 ft. (Dewalque.) France. Liasien beds, 500 ft. (D'Orbigny.) Sinémurien beds, 1,000 ft. (D'Orbigny.)
3. RHÆTIC. Maximum, 100 ft.	Maximum, 50 ft. (J. B. Jordan.)	Belgium, thin and variable. (Dewalque.) Austrian Alps, 50 ft. (Gümbel.) Kœssen beds, 50 ft. (E. Suess.)
2. TRIASSIC. Keuper, 1,100 ft. Bunter, 900.	Keuper, 3,400 ft. max. (J. B. Jordan.) Bunter, 1,500 ft. max. (J. B. Jordan.) Keuper, 1,500 ft. max. (Ramsay.) Keuper, 1,000 to 1,700 ft. Bunter, 600 ft. Cheshire and Lancashire. (Ormerod.)	Hartz, Bunter, 1,000 ft. (V. Meyer.) Austrian Alps, Bunter, 2,800 to 3,200 feet. (Gümbel.) Dachstein beds, 2,000 ft. (E. Suess.) Hallstadt beds, 800 to 1,000 ft. (E. Suess.) Guttenstein beds, 150 ft. (E. Suess.) Werfen beds, very variable. (E. Suess.) Würtemberg, Keuper, 1,000 ft. (Alberti.)
1. PERMIAN. Perhaps 100 ft.	Upper Permian, 1,500 ft. (J. B. Jordan.) Lower ,, 3,000 ft. (J. B. Jordan.)	

The Irish Permians cannot exceed 100 feet in thickness in any place where they are seen. According to King and Baily their fossils prove them to be equivalent to the Durham and Yorkshire rocks, that is, the "Middle Permian" of Lyell. Yet these Irish rocks are the base of the Triassic, and merge so gradually into them that they could not have been separated from them but for their fossils. In the valley of the Lagan (cos. Down and Antrim) the rocks lying upon them are said to be the representatives of

the "Bunter Sandstone," while in the co. Tyrone the rocks in immediate contact have the character of the "Keuper Marl."

Above the Triassic are the "Rhætic," or the passage beds from them into the Jurassic. In those places where the upper beds of the Rhætic have not been removed by denudation, they form a complete sequence between the Triassic and the Jurassic, although their thickness is in some places less than 20 feet, increasing on the north side of Belfast Lough to only something over 100 feet. Evidently they thin away south-westward and westward, as do also the underlying Triassic rocks.

The Jurassic rocks are only represented by a portion of the Lias, and that but sparingly, as the greater portion of these rocks seems to have been removed by denudation prior to the deposition of the Cretaceous strata. Enough, however, of them are preserved to show their relations to the underlying Rhætic, and to prove the thinning away of the latter towards the westward and south-westward.

The rocks belonging to the Irish Permian, Triassic, and Jurassic were evidently deposited respectively in waters of very unequal depths. In the neighbourhood of Belfast Lough the sequence consists of more members than in the counties of Tyrone and Londonderry, besides being of a much greater thickness. The thicknesses, however, suddenly vary in the latter area, as near Stewartstown, co. Tyrone, the Trias cannot be more than thirty feet thick, while a little to the north at Croagh it is over 280 feet, but a little farther northward, in Londonderry, it is less than 50 feet.

Belfast Lough.		*Tyrone and Londonderry.*	
5. Lias.		Lias.	
4. Rhætic, maximum	100 feet	Rhætic, about	25 feet
3. Keuper, "	1000 "	Keuper. Very variable, maximum	
2. Bunter, "	1000 "	about	300 "
1. Permian.		Permian.	

In both these districts the sequences ought to represent the same period of time, that is, from the Permian to the Lias, unless indeed, which is not impossible, the Permians are only "shore beds" of the Triassic. In this case the Tyrone Permians may have accumulated on a higher horizon than those in the vicinity of Belfast. That in both areas there are continuous regular

sequences seems to be proved; for whether the Rhætic beds be thick or thin, there is no hard boundary above or below them; in all localities they graduate imperceptibly upwards into the Lias and downwards into the Keuper Marls; furthermore, the latter, in the co. Tyrone, merge into the Permian,* but near Belfast, into the Bunter Sandstone, while the relations between the latter and the underlying Permian is not so manifest.

Notwithstanding these regular and continuous sequences we are asked to believe that during intervals of greater or less duration, strata ceased to accumulate in this area during the period of time when the rocks, not represented in this country, were being deposited; and that, as the Irish Permians of Belfast and Tyrone are equivalents of the Middle Permians, there must be a hiatus above them answering to the period during which the Upper Permians were accumulating elsewhere; and that in the co. Tyrone there must be a much greater hiatus left by the absence, not only of the Upper Permian, but also of the Bunter Sandstone, and so in various other cases.

In this way the thickness of formations is too often calculated. The geologist does not carefully and separately work out each basin of deposition, and endeavour sufficiently to make out by comparison what beds or system of beds are the representatives and equivalents of those found in adjoining or distant basins, but he tries to fit in all together. He takes a bed or system of beds from one basin and puts them into another; then the rocks of this basin with those added have a place found for them in, above, or below the rocks of another basin, until at length a magnificent structure is erected—very imposing and ingenious—but without sure foundation, and inconsistent with what we may conclude from the operations which we can see going on around us at the present moment. Thus, formations are made to be of much greater thicknesses than what they can have really attained to.

Unfortunately for Geology there are difficulties in the way of its becoming a true science. First, there is the necessarily great room for conjecture which leaves such a vast field open for sensationalists and speculators; and secondly, as in other branches of science, some investigators are apt to be so strongly taken

* The limestones at Templereagh, co. Tyrone, which contain Permian fossils, are said to have been interstratified with the Keuper Marls.

possession of by first impressions and conclusions that they cannot emancipate themselves from them. Romanes has compared these to Professor Möbius' educated pike, who when he was thoroughly impressed with the fact that he was separated somehow by an invisible barrier from the minnows in the adjoining tank, could not afterwards unlearn his lesson though the barrier had been removed. So with these men; they cannot learn "when the hand of science has removed a glass partition."

It seems to me, therefore, that there should be more caution used in the comparison of supposed corresponding strata in different districts. Frequently there is a too direct and close correlation instituted between them, when they may have in reality no more than the general, but most important, connexion, that they were both formed, more or less probably, in about the same portion of a certain geological period. It is frequently the too hasty generalization respecting the formation of more or less nearly contemporaneous rock groups, occurring in two different places, which leads to the supposition of a hiatus in one of the places, when it is found that the correlation of all the groups cannot be carried out.

Geology seems, from the nature of the case, to follow the course of other branches of knowledge. At first, ascertained phenomena form little more than an unarranged, undigested mass of facts. Afterwards these are put into order, and general connecting laws and principles, more or less correct, are deduced. Then, at a still later stage, it is found from further induction and more critical consideration of facts, that in many cases and respects generalization has been too sweeping and carried too far, and that it has to be limited and modified by subordinate and less obtrusive principles, so as to become more strictly scientific. Geology seems now to have reached this stage, at least as regards several of its branches. It is now not so much the bewildering variety of a crowd of uninterpreted phenomena which oppresses us, as the complexity of their relations, so many of which have been discovered. I would, therefore, respectfully enjoin upon my brethren of the hammer more circumspection than what they sometimes display, lest that by adhering too strongly to insufficiently guarded generalizations characteristic of an earlier stage of Geology, they may be contributing to the perpetuation of that stage, and unconsciously retarding the progress of discovery.

XXVII.—ON THE EVIDENCE IN FAVOUR OF THE BELIEF IN THE EXISTENCE OF FLOATING ICE IN INDIA DURING THE DEPOSITION OF THE TALCHIR (PERMIAN OR PERMIO-TRIASSIC) ROCKS, BY V. BALL, M.A., F.G.S.

[Read February 16th, 1880.]

THIS communication is made to the Society in response to a special request by the Rev. Dr. Haughton that I should give a statement of the facts which are relied upon by the Geological Survey of India in support of the view that a glacial period—or rather a period of, perhaps, only seasonal great cold existed in early Geological times in tropical India.

The case which I have to lay before you rests upon evidence very similar, as all must admit, to that which is employed in support of the now pretty general belief that periods of great cold (glacial periods) have occurred in now temperate climates at ages not very far distant, geologically speaking, from the present.

It is now about twenty-five years since the Geological Survey of India, as constituted under the directorship of the late Dr. Oldham, commenced operations on the coal fields by exploring one which is situated in the native state of Talchir in the Province of Onisa. The officers so employed* were the first to discriminate a group of rocks which underlay the coal measures and from which they were found to be separable not only by very marked lithological characters, but also by an amount of more or less distinct unconformity.

This group of rocks consisted of fine-grained, yellow, and greenish sandstones, green, blue, and yellow mud-stones or silts which latter, on exposure, became fractured into finely splintered fragments and one or more boulder beds of so remarkable a character as to excite the particular attention of the geologists who in their account which was published in the first Volume of the Memoirs of the Survey, described the bottom boulder bed as

"Consisting essentially of boulders of granite and gneiss, those of the former comparatively small, and the latter of much larger size, frequently

* Messrs. W. T. and H. F. Blanford and W. Theobald.

four to five* feet in diameter imbedded in a matrix which varies from a coarse sandstone to the very finest shale.

"In some places the matrix is a dark-green silt without any admixture of sand, but full of boulders of all sizes. Occasionally it is very fine in grain, and sometimes assumes a shaly structure.

"The question naturally, indeed inevitably suggests itself, how these enormous blocks of stone, manifestly requiring a great force to abrade and transport them are found mixed with a sediment so fine that in any except a very sluggish current it must have been swept away, and could not have been deposited?

"Should any evidence hereafter accrue allowing the inference that these beds may have been formed in a lake on a high table-land, where the winter temperature was sufficiently low to admit of ice reaching the waters of the lake without melting, then an adequate explanation of the phenomenon may be given, as it resembles exactly the effects of the action of ground-ice which enabling boulders to be carried down by a sluggish current, would undoubtedly produce such an intermixture of large rounded masses of rock and of fine silt as is seen in the present case.

"Possibly a more minute examination of the boulders may reveal groovings and scratchings on their surfaces. The presence of these however on the supposition of ground-ice having been the means of transport, should not by any means be looked for with certainty, and their much rounded condition† seems quite opposed to the idea of transport by true Glaciers.

"It must be borne in mind that the temperature necessary to allow of Glaciers reaching the sea or a lake is very much lower than that at which ground-ice might be formed and carried down by rivers. While the existence of the former is determined by the mean temperature of the whole year, the latter depends on the lowest temperature of the winter season, and therefore may readily and does occur in countries whose mean temperature is comparatively high.

"Thus in the northern part of the Black Sea at the present day, coast ice is always formed in winter, and this too in salt water; the winter temperature there being equivalent to that of Central Norway, which is only a degree or two south of countries in which Glaciers come down to the sea level; while, on the other hand the summer

* In areas which have subsequently been examined boulders having diameters three times as great have been met with.—V.B.

† This is not invariable as I have observed the deposit in some places to include sharply angular masses.—V.B.

temperature is equal to that of Central Spain. An example perhaps more to the purpose is found in Thibet where all the conditions under which such a deposit as that we are considering might be produced, exist. The winter temperature of Thibet is as low as that of the Black Sea, the country lying between the January Isothermals of 23° and 41° F. while in summer the temperature is equal to that of Sierra Leone, Ceylon and Southern India the July Isothermals being between 77° and 81° F."

For a long time these views did not meet with general acceptance and like some others of my colleagues, I attempted shortly after reaching India to offer an explanation* which did not employ ice as an agent in the transport of the boulders; but the discoveries subsequently made and which I am about to describe have compelled me to make a public recantation of this heresy and to acknowledge that the original theory is the only one capable of explaining the facts.

The progress of the Survey has served to render it possible to indicate closely the limits within which the deposit occurs; but it will be sufficient for present purposes to say that the area lies within the 77° and 88° meridians of East Long., and the 16° 30° and 25° parallels of North Lat.—thus occupying the central and most elevated part of the northern half of the Peninsula. Throughout this wide tract the beds occur scattered about but present a wonderful uniformity of appearance, the original lithological description being applicable to the rocks at the most distant localities.

In the year 1872 Mr. Fedden, when examining the valley of the Pem River ten miles W.S.W. of Chanda, discovered† a boulder bed resting upon a compact Vindhyan Limestone which where it was exposed, for a distance of about 330 yards, displayed a polished, grooved and scratched surface which it was incontestibly ascertained was not only not of modern origin but was, where uncovered, just becoming obliterated. Among the boulders one about two feet in diameter consisted of a hard, dense, close grained syenitic granite and had one of its sides beautifully polished and scored and striated.‡ This specimen is now in the Geological Museum at Calcutta.

* Vide Mem. Geol. Sur. India, Vol. VI., p. 116, *note*.

† Records Geol. Surv. of India, Vol. VIII., p. 16.

‡ These appearances were accepted I believe by Mr. Campbell, Author of "Frost and Fire," during his visit to India, as distinct indications of Glaciation.

From the character of the striæ on the rock surface it was concluded that the movement, supposing there to have been no subsequent shifting of levels, had been up the slope—the ice-raft, which it was concluded bore the boulders, having drifted against the rock and been impelled forwards.

As the surface at present stands the nearest locality, judging by the Geological Map, from which the syenite boulder might have been derived, lies thirty to forty miles to the East where crystalline rocks are indicated at a lower level—the rivers now flowing in that direction. Since, however, the nearly adjacent country to the west is covered by the Tertiary, Dekan trap, it is impossible to assert in what direction the original source may have been, and regarding this point Mr. Fedden makes no suggestion.

In quite a different part of the country—in Western Bengal—I have met with what, so far as the rocks are concerned, is quite the converse. There in two distinct coal fields, I have found boulders of a Vindhyan quartzite mixed with others of gneiss granite, &c., resting on beds of gneiss. So far as is at present known the nearest possible source for these is from fifty to eighty miles distant respectively, and it is likewise situated at a lower level—a very rough and broken country, through which the rivers traverse many a rocky defile, intervening.

Such cases as the above clearly cannot be explained by river* transport, the movements of mud or of turf, while the suppositions that the beds are merely marginal or that the silt was deposited on an already boulder-strewn surface are also incapable of affording an adequate explanation.

One very remarkable fact about the Talchir rocks is that they constitute the oldest formation in Peninsular India in which any trace of life has been met with. The great Vindhyan series to which allusion has been made above, with its vast thicknesses of sandstone and limestone has not, in spite of unremitting search,

* The effect of modern rivers is to erode out and isolate these boulders, a remarkable instance of which I have noted in the Goinghatta river in Sirguja where "In several of the reaches a peculiar effect is produced by the gneiss boulders which have been washed out of the boulder bed and are scattered about on the surface, as though they had been only just dropped from floating ice. One boulder still *in situ* in the bed gave the following dimensions 7′ 4″ × 6′ 8″ × 2′ = 97 cubic feet and I observed several others, which could not be measured, which were still larger." Record Geol. Survey, of India. Vol. VI. p. 29.

yielded the slightest trace of any organism, and the older formations are likewise unfossiliferous.

Be the Vindhyans of Devonian age, as seems probable, or not, it is at least certain that a long interval, during which erosion and denudation were active, elapsed before the conditions arose which accompanied the deposition of the Talchir boulder bed. The fossils found in the strata immediately succeeding the boulder bed consist of a meagre assortment of ferns and *equisetaceæ** such as might have existed on the borders of a lake in a damp temperate climate. There is not the faintest trace or indication of any marine action, whether of deposition or otherwise, having been in operation throughout the duration of this and several of the succeeding periods. On the other hand, the evidence, so far as it goes, points to the rocks having been deposited in fresh water lakes—as were the succeeding coal measures, and the next following formations—but the fossils of these latter indicate a much warmer, probably a truly tropical climate.

A tempting means of explaining this state of things is offered by the supposition that Peninsular India formed part of a lofty table-land similar to Thibet at the present day, and that as the plateau subsided the climate from being at first one with very cold winters gradually became warmer. We have, in Western Bengal, evidence that the Talchir beds have been affected by considerable local disturbance and alternation of level, but more direct evidence of the existence of a lofty plateau is wanting.

On the whole it would appear to be safer to refer the phenomena to some widespread or cosmical condition of the climate, and when viewing the question from this point of view we have the striking coincidence that the Permian breccias of England are regarded by Professor Ramsay and others to be of glacial origin, and that the Karoo Boulder beds of South Africa, which are likewise of Permian age, are described by Mr. Griesbach, also, to indicate a glacial temperature. And here I may add that I understand that Mr. Griesbach, who is now a member of the Geological Survey of India, reports a striking identity to

* It is noteworthy that the soil derived from the Talchir rocks is generally a very poor one as compared with that from the rocks of subsequent periods wherein vegetable life was more abundant.

exist between the lithological characters of these two deposits; but on this point we shall doubtless hear more ere long.

The Physical Geography of India at that time was undoubtedly very different from what prevails at present. The Peninsula was at first probably unconnected with Eastern Asia, and the Himalayas; while, from the similarity of the fossils in the coal measures of India with those of the upper (triassic) portion of the Australian coal measures, and those of the later portion of the Karoo beds, it has been argued that India was then in connection with Australia and Southern and Western Africa. As the cold of the Talchir times was withdrawn both animals and plants appear to have spread over the whole area, and the migration then commenced appears to have continued down to Miocene or Pliocene times when the Indian Giraffe and Ostrich, the remains of which are found in the Sivalik deposits, appear to have marched off bodily to Africa leaving no living representatives behind them. The strong African element in the Indian, or Indian element in the African fauna of the present day proves the intimate connection which existed between these countries at no very distant period; but into this subject I must not further wander.

At what period the Himalayan region, and Eastern Asia with it, became permanently connected with the Peninsula is uncertain, but probably the Eastern portion was, for a time at least, during the deposition of the coal measures continuous with India since there are at the foot of the Sikkim Himalayas, coal measures with plant fossils identical with those of the Peninsular fields.

Evidence too of much colder climates than that now prevailing in the Himalayan region in comparatively recent times is afforded by undoubted traces of glaciers as described by Major Goodwin Austen at elevations of only 5,000 feet above the sea. And according to Mr. Theobald there are old moraines in the Kangra district, at elevations of only 2,000 feet above the sea, but his conclusions are disputed by other authorities. One class of observations, however, show that a temperate climate must have prevailed in India at no very distant period, and if then why not also in Permian times?

The class of observations I refer to are those connected with the characters of the fauna and flora which exist on the High-

lands of Southern India. Animals and plants of distinctly Himalayan types can only have forced their way to these isolated peaks when the cool climate of the intervening country admitted of their migration; with advancing heat they betook themselves to the peaks and so became cut off from their original connection.

Mr. W. T. Blanford, in the recently published manual of the Geology of India, has pointed out that boulder beds of somewhat similar character to that of Talchir age are found in other Indian and Himalayan formations, and suggests that they may perhaps indicate the existence of cold climates during their deposition. They are:—

1. In Transition rocks of uncertain age in Jessalmir, where a striation of underlying formations was observed.

2. Silurian? Slates at Pangi, S.E. of Kashmir, which contain boulders in great numbers.

3. Boulders in clay, supposed to be upper cretaceous, in the Salt range. One block was found to be polished and striated in a very characteristic manner on three faces.

I do not propose to make any attempt to explain how such periods of great and abnormal cold have been caused in past ages of the earth's history. With such questions Physicists and Astronomers are the proper persons to deal. To the geologist falls the task of observing facts and phenomena, and drawing what appears to him to be the legitimate deduction from them. I believe I am correct in saying that all of my colleagues who have had an opportunity of studying the Talchir boulder bed are now unanimous in accepting Mr. Blanford's theory of its origin.

In conclusion, I have only to say that in the preparation of this statement I have freely used the published views on the subject of my colleagues and other sources of information which may be regarded as the common property of the Geological Survey of India.

XXVIII.—ON THE COAL FIELDS AND COAL PRODUCTION OF INDIA, BY V. BALL, M.A., F.G.S., GEOLOGICAL SURVEY OF INDIA, HON. SEC. ROYAL GEOLOGICAL SOCIETY, IRELAND.

[Read 21st April, 1879.]

[This Paper was in substance also read at the meeting of the British Association held at Sheffield, 1879.]

ALTHOUGH a paper on the coal fields of India by the late Colonel Meadows Taylor, has been published in the Journal of this Society,* I venture to think that an account of them by one who has had an opportunity of examining many of them will not prove unacceptable at the present time.

Colonel Taylor's compilation was made from the publications of the Geological Survey of India in 1873, since which time there has been considerable and most important progress, both in field work and in the determination of the homotaxy of the fossil floras, which have been obtained in the Indian coal-measure and associated rocks.

At the last meeting of the British Association which was held here† in Dublin, I exhibited and described an early issue of the new Geological Map of India, which had been prepared to illustrate a Manual of the Geology of that country, written conjointly by the Superintendent of the Survey, Mr. H. B. Medlicott, F.R.S., and the Senior Deputy-Superintendent, Mr. W. T. Blanford, F.R.S. This manual, though it has been printed, has not yet come to hand.‡ From the small scale of this map, 64 miles to the inch, it is necessarily but little more than an index, merely indicating the limits of the principal formations.

For large tracts of India, however, maps on larger scales

* "On the Coal Fields of Central India, from the Reports of the Geological Survey of India, and other official sources." By Meadows Taylor, V.P.R.G.S.I., Jour. Roy. Geol Soc., Ireland. New series, Vol. III. Exception must be taken to the use in this title of the term *Central India*, since there are no coal fields in Central India *proper*, though there are in the Central Provinces.

† *Vide* "British Association Reports," Dublin, 1878, p. 532.

‡ It has been received since the above was written, and has been freely used in the final preparation of this paper for press.

showing the minor details and subdivisions already exist and a selection of these referring to the coal fields I now exhibit.

Broadly speaking, it may be said that there are two geologies in India, namely: that of the Himalayas and that of the peninsula proper. The former conforms in character with the recognised classification adopted in reference to European formations, while the latter differs from that of any other well-known region in the world.

Several of the formations occurring in peninsular India spread uninterruptedly over hundreds of thousands of square miles. It would, in fact, be possible to mark out areas within the limits of which two of these formations respectively prevail, which would be equal to the British Islands.

On the present occasion it will be unnecessary to offer any sketch of the general geology, my object being to direct attention to one formation, or rather to a system of formations, and to them more particularly in reference to the coal which they contain.

My principal reason for preparing this account is that I find that a considerable degree of misconception exists as to the extent and value of our Indian coal fields. At the same time, from the frequency of the inquiries which have been made of me, I conclude the subject is one which many regard as being of great interest and importance.

To India, indeed, it is one of vast, imperial importance, since the development of her natural resources, and the increase of local manufactures consequent thereon, seem to offer a remedy the most efficient towards establishing the equalization of the exchange.

The following is the classification of the subdivisions of the Gondwana system, which is at present recognised by the Geological Survey of India:—

			Thickness
MESOZOIC	Upper	Cutch and Jabalpur Rajmehal and Mahadeva *	11,000 feet.
PALÆOZOIC	Lower	Panchet Damuda; Raniganj or Kamthi Ironstone Shales and Barakar Kaharbari and Talchir	13,000 ,,

* The Kota Maleri beds alluded to below in the account of the Wardha field may be interpolated here.

Dr. Feistmantel, the Palæontologist of the Geological Survey of India, has, on the evidence afforded by the fossil plants, offered the following detailed correlation with European formations:—

Upper	Cutch and Jabalpur	= Lr. Oolite	
	Rajmehal	= Lias	
Lower	Panchet	= Keuper	Trias
	Damuda, Talchir	= Buntsandstein	

How far such identifications between parts of the world so remote from one another are to be relied on is perhaps open to question. There is much, no doubt, to be said upon both sides. It will only be possible for me to allude very briefly to the principal points at issue; but before doing so, I propose to describe the leading characteristics of the several groups which constitute the lower portion of the above classification.

The Upper Gondwanas being of little economic importance, though of great interest otherwise, may be passed over in this communication. The two are probably separated by a very distinct break in time, as the lower are often much disturbed while the upper maintain their original horizontal positions. Taking the groups successively in ascending order, the lowest is the—

TALCHIR GROUP.—The rocks composing this group consist of sandstones, fine shaly silts, and boulder beds, all of which are commonly of greenish or buff colours. The maximum thickness is 800 to 1,000 feet, but in many of the fields it does not amount to more than about one-fourth of that amount. These rocks are found at the base of all the coal fields, and also in many outlying tracts where they are not in contact with newer deposits. Of special and general interest to geologists is one variety of boulder bed, as it affords evidence of the existence of floating ice at the time of its deposit in latitudes running as low as 16° 30′ N.

But as a paper by me on this subject has already been published in the Journal it will be unnecessary to enter further into details again. It is of importance, however, to reiterate the fact that in these rocks we find the first traces of life in India, the vast thicknesses of rock deposited in previous periods being, so far as we know, unfossiliferous. These first forms consist chiefly of equisetaceous plants and ferns, all of them, I believe, such as might have existed in a moderate temperate climate.

The area through which, often at widely separated intervals exposures of these beds are scattered, may be roughly indicated by saying that it occupies the higher central parts of the peninsula, being bounded by the 77° and 88° meridians of east longitude, and the 16° 30′ and 25° parallels of north latitude.

The Talchir beds are of no economic importance, save that they contain several varieties of easily worked, durable, and sometimes ornamental building stones. Limestones are rarely found, generally they occur merely as concretionary masses in other rocks. From their scattered distribution and limited extent, they can scarcely be expected ever to prove of much value.

KARHARBARI GROUP.—This group of beds, which consists of conglomerates, sandstones, and coal, was long considered in consequence of the strong lithological resemblance which its members bore to the Barakar rocks to belong to that group. Recent palæontological investigations, by Dr. Feistmantel, are considered to be of sufficient weight to cause it to be classed in closer proximity to the Talchir group, a number of species of plants having been found common to both; but the physical relations between the Karharbari beds and those of the Talchir group seem to be identical with those existing between the Barakars and the latter, and there is not any sign in the lithological characters, or in the conditions of deposit thence deducible common to the Talchir and Karharbari groups. Atempts to point out lithological distinctions as existing between the Karharbari and Barakar beds appear to me to be somewhat strained, and not very successful. The differences are simply such variations as might have been determined by local conditions of deposit. I believe, therefore, that the fossil evidence merely proves a survival of certain species, and cannot be taken to counterbalance the geological evidence as to a marked separation between the deposition of the Talchir and succeeding groups.

The Karharbari rocks were named after the coal field bearing that title; they have also been identified at Mopani. Their thickness is 500 feet.

BARAKAR GROUP.—This group of rocks, from which, as I have said, I believe the Karharbari beds cannot be separated, consists of sandstones, grits, pebble conglomerates, conglomerates with angular

fragments, carbonaceous, and other shales and coal. Except in some of the eastern fields of the Damuda Valley series, this group includes all the valuable coal of Peninsular India.

The thickness attains its maximum in the Jeriah coal field where it is estimated to be 3,800 feet. In the Ranigunj fields it is 2,000 feet; in most of the other fields it is much less.

IRONSTONE SHALE GROUP.—This group, consisting of bands of ironstones, running through gray and black (carbonaceous) shales, overlies the Barakar group with general conformity. It is only found in the Damuda Valley fields, wholly disappearing further west.

In the Bokaro field it attains its maximum thickness of 1,500 feet.

RANIGUNJ (KAMTHI) GROUP.—The Ranigunj group consists of sandstones which are fine-grained and often calcareous, carbonaceous shales and coal. The coal is generally of better quality and more uniform in composition and in the thickness of seams than is that of the Barakar group. In the easternmost field of the Damuda Valley series, namely, the Ranigunj which has given the name to the group, the principal coal seams which are worked belong to this group. In the more western fields, it steadily thins out the coal becoming of less and less importance.

In the central fields of the peninsula it is very much changed in lithological characters and is so greatly increased in thickness amounting to from 5,000 to 6,000 feet, that the true identity with it of these latter deposits which constitute the so-called Kamthi group is established only by general geological relations aided by fossil evidence.

The rocks of the Kamthi group are largely made up of coarse sandstones and conglomerates in which there is a prevailing reddish colour due to the amount of iron always present. Coal rarely occurs as a member of this group; its importance is insignificant.

For fuller accounts of the lithological characters and fossil contents of the above beds I must refer the reader to Mr. Blanford's account of them in the Manual of the Geology of India.

The groups of the upper Gondwanas do not contain workable coal, but their presence in the several fields covering and sometimes wholly concealing the coal-measures confers on them indirectly a considerable economic importance.

AGE OF THE PLANT-BEARING SERIES OF ROCKS INCLUDED IN THE GONDWANA SYSTEM.

I have already given the proposed correlations of the several series or groups of Gondwana rocks, with European formations, but it may be well to add a few general remarks on the subject.

Some of those now present who are readers of the *Geological Magazine* may, perhaps, have scented the battle which has been waged afar off, as to the homotaxy and correlation of these rocks with those of the recognised European sequence.

Perhaps the most important recent result of the examination of the fossil plants has been the discovery that *Glossopteris* (a genus of ferns), which was formerly thought to be characteristic of the lower Gondwanas has been found to occur in the very highest group of the upper Gondwanas, viz., Jabalpurs. On the other hand several species of cycadaceous plants, which order was supposed to be restricted to the upper groups, have been found to exist in the lower or Damuda groups,* thus to a great extent binding the whole system of groups or series together, and drawing them away from the floras characteristic in other countries of palæozoic periods.

But what have been called palæontological contradictions occur in these rocks, for it has been found, with reference at least to some of the higher or younger groups, that the marine faunas, where present, do not always point to the same conclusions as the floras.

In the annual report of the Survey for 1876, this state of things was summarised by Mr. H. B. Medlicott in the following words:—

"The facts of our Gondwana rocks are certainly puzzling to systematists. On the west, in Kach we have the flora of the top Gondwana group, which has a Bathonien *facies* associated with marine fossils of Tithonien affinities; while on the S.E. in the Trichinopoli group, beds, with *flora*, so far as known, like that of the Rajmahal group, which is taken to be liassic, have been described by Mr. H. Blanford as overlaid in very close relation by the Otatoor group, the *fauna* of which has been declared upon very full evidence to have a Cenomanien *facies*."

* The Damuda Cycadaceous plants are—*Noeggerathia Hislopii*, Bunb., *Macropterygium*, Comp. *Brownii*, Schimp., *Pterophyllum Burdwanense*, Fstm., *Glossazamites Stoliczkanus*, Fstm., *vide* "Records Geological Survey of India," Vol. X., pt. 2.

Another instance of these contradictions I quote from the "Manual," p. 100:—

"The Kota beds with their liassic fish have now been so closely connected with the Maleri clays and sandstones containing triassic reptiles and fish, and jurassic fish, that both are classed in the same group."

The occurrence of several genera of Damuda plants more particularly *Glossopteris* in the higher Australian coal-measures, passing thence downwards into beds containing carboniferous marine fossils, and, lower still, typical carboniferous plants has been used as an argument in favour of the view that our Indian coal-measures are palæozoic. Dr. Feistmantel maintains, however, that the Australian upper coal-measures are triassic, while the lower are undoubtedly carboniferous, *Glossopteris* having survived.* Some of the Australian sections, however, scarcely support the view of a distinct separation being possible.

Mr. W. T. Blanford is of opinion that:—

"The whole evidence, so far as it goes, both of animals and plants, tends to connect the whole of the Gondwana series, with formations ranging from the upper palæozoic (Permian) to the lower jurassic."

It is clear that *floras* alone afford but an unsafe guide to correlation, and for this reason that they, as well, also, as some land animals appear to have often survived the wholesale changes which have affected the faunas of the neighbouring seas and oceans.

Although, therefore, it may be dangerous to attempt a close correlation of the Indian formations with those of distant countries by the evidence afforded by fossil plants, still the advantage of employing such evidence as a means of identification between widely separated deposits within the limits of India cannot be doubted.

ORIGIN OF THE GONDWANA ROCKS.—From the evidence afforded by the fossils, and the lithological characters of the rocks, it is probable that the Gondwana strata were deposited in a series of river valleys not unlike those which constitute the Indo-Gangetic plains at the present day. The rivers were generally sluggish in their movements and occasionally may have formed lakes.

AREAS OF GONDWANA ROCKS.—The following table of the areas

* I lately received from Professor Boyd Dawkins some specimens of *Glossopteris* and *Vertebraria* from the base of the coal-measures at Wallerawang, N. S. Wales. They appeared to me on casual examination to be identical with Damuda species. And the resemblance in the lithological structure of the shale including them, to a common Damuda rock, was no less striking. The specimens have been sent to India for critical examination and comparison.

of the Indian coal-measures, and associated younger rocks which may conceal coal-measures, has been drawn up by my colleague, Mr. Hughes:—*

Godavari and affluents, . .	11,000 square miles.
Sone, ...	8,000 ,,
Sirguja and Orissa, &c., . .	4,500
Assam, ...	3,000 ,,
Narbuda and affluents, . .	3,500 ,,
Damuda, ...	2,000 ,,
Rajmahal area, . . .	300 ,,
Unsurveyed, &c., . . .	2,700 ,,
	35,000 ,,

For the sake of comparison other countries with greater areas are enumerated:—

United States, . . .	500,000 square miles.
China, . . .	400,000 ,,
Australia, . . .	240,000 ,,

India comes next or fourth on the list. Although I believe Mr. Hughes' estimates require some modifications in detail, still the total cannot be far from correct, and 30,000 square miles might I think, perhaps be safely adopted as a minimum.

List of Separate Coal Fields.

Bengal.

1. Rajmahal Hills, . 2. Birbhum, . . . 3. Deogurh, . . . 4. KARHARBARI,† . .	North of Damuda River.
5. RANIGUNJ, . . 6. Jeriah, . . . 7. Bokaro, . . . 8. Ramgurh, . . 9. Karanpura, N. . . 10. Karanpura, S. . .	Damuda Valley.
11. Chopé, . . . 12. Itkuri, . . . 13. Aurunga, . . . 14. Hutar, . . . 15. DALTONGUNJ, . .	West of Damuda Valley.
16. Tattapani, . . 17. S. Rewah and Sohagpur, 18. Jhilmilli, . . . 19. Bisrampur, . . 20. Lukanpur, . . 21. Rampur, . . . 22. Raigurh and Hingir, . 23. Udaipur and Korba, . *Orissa.* 24. Talchir, . . .	Sone and Mahanadi Valleys.

* "Records," Vol., VI., p. 65. † Fields which are worked printed in capitals.

Central Provinces.

25. MOPANI, . . .	Satpura Region.
26. Tawa, . . .	
27. Pench, . . .	
28. Bandar, . . .	Godaveri Valley.
29. WARDHA or Chanda, .	
30. Kamaram, . .	
31. Singareni, . .	

Sikkim.

32. Sikkim.

Assam.

33. Makum, . . .	Valley of the Bhramaputra.
34. Jaipur, . . .	
35. Ńazira, . . .	
36. Jangi, . . .	
37. Disai, . . .	

In the above list, localities, chiefly situated in the north-west provinces where Tertiary coal occurs, but not in sufficient quantity to constitute workable coal fields, have not been included.

Of the thirty-seven separate fields only five are at present worked with regularity. These are Ranigunj, Karharbari, and Daltongunj in Bengal, and Mopani and Wardha in the Central Provinces.

In the following abbreviated notes I endeavour to give the chief points of importance regarding each field, while the references to the publications of the Geological Survey will indicate the sources from whence fuller details may be obtained :—

LOWER BENGAL.

I.—RAJMAHAL AREA.*

The Rajmahal Hills form a series of low plateaus, which are situated at the point where the Ganges turns southwards to form the head of its delta.

The formations in this area, which are connected with the coal-measures, are in descending order as follows:—1. Laterite. 2. Rajmahal Group, consisting chiefly of contemporaneous traps with beds containing fossil plants 1,500 feet. 3. Dubrajpur group = (Mahadevas) 450 feet. Barakar group (= coal-measures). 5. Talchir. These cover a total area of about 4,000 square miles. The coal-measures are exposed over seventy square miles, but doubtless extend over a vastly greater area underneath the

* Ball, "Mem. Geol. Survey of India," Vol. XIII. Also "Manual," pp. 165, 171.

younger formations. Separated by these overlying rocks, four distinct areas or fields may be enumerated—1. Hura; 1. Chuparbhita; 3. Pachwara; 4. Mhowagurhi; 5. Brahmini. These are all on the western margin of the hills. It will be an interesting and economically important point to decide, whether the coal-measures extend underneath the traps, &c., to the east. If so they would be close to the water carriage of the Ganges.

The coal is, for the most part, stony and bad. It is not now regularly mined, but a large quantity was extracted during the construction of the East Indian Railway.

II.-III.—Birbhum, Deogurh, &c.*

A number of small detached basins or outliers occur in the districts of Birbhum and Deogurh where metamorphic rocks mainly prevail. They are of little or no economic importance, and may be passed in this record without further notice.

IV.—Karharbari or Kurhurbali.†

This small field, having an area of only 11 square miles, and which is situated in the district of Hazaribagh, at a distance of 200 miles from Calcutta, by rail, is one of great importance, both from its position and the quality of its coal. The sedimentary groups of Gondwana rocks represented in this area are Barakar and Kaharbari, 500 feet (=coal-measures) and Talchir, 600 feet.

The coal occurs in three principal seams which have an average total thickness of sixteen feet. They spread over an area of 8½ square miles. The amount of coal may therefore be estimated at 1,360,000,000 tons, and the available portion of this at 80,000,000.

A sample assay gives the following results—carbon, 66·3; volatile matter, 23; ash, 10·7. In working power; the Karharbari coals are to those of the Ranigunj field as 113 : 100.

Several companies are engaged in working mines in this field, namely, the East Indian Railway, the Bengal and the Equitable. Owing to the want of any proper system of registration in India, it is impossible to give accurate statistics, but I believe that up to June, 1875, the East Indian Railway had extracted 350,000 tons.

* Hughes, Mem. Geol. Survey of India, Vol. VII., pp. 247, 255. Manual, p. 171.

† Hughes, *loc. cit.*, p. 299.

The following I quote from the report of the Company for the year 1878:—

"The out-turn of steam coal and rubble from the Company's collieries, during the year 1878, was 208,790 tons. The quantity consumed on the main line was 162,370 tons, at an average cost (exclusive of carriage) of 5*s.* 5*d.* per ton; and on the Jabalpur line, 17,600 tons, at an average cost of £1 2*s.* 4¾*d.* per ton (carriage included). Regular mining was not commenced in this area till about ten years ago, when a branch from the main trunk line brought the coal into successful competition with that from Ranigunj, twenty-three miles being saved in the journey up country."

V.—RANIGUNJ.*

This field is situated on the rocky frontier of Western Bengal at a distance of 120 miles from Calcutta.

The groups represented with their respective thicknesses are as follows:—

Upper Panchet or Mahadeva, . . .	500 feet
Panchet, ...	1,500 „
Ranigunj, ...	5,000 „
Ironstone shale, ...	1,400 „
Barakar, ...	2,000 „
Talchir, ...	800 „
Total,	11,200 „

The Ranigunj coal-field is the largest and most inportant of the areas in which coal is worked in India. Its proximity to the main line of railway, and also to the port of Calcutta, tends to give it pre-eminence over other less favourably situated localities. The total area of coal-bearing rocks which is exposed is about 500 square miles; but it is possible that the real area may be even double that; since on the east the rocks dip under, and are completely concealed by, alluvium. Throughout this area a central zone includes the principal mines, and the chimneys which dot this tract constitute it the black country of India. In the year 1774 coal was known to occur there, and so long ago as 1777 was actually worked. In 1830 several collieries of considerable extent had been opened out and were, we have reason to believe, in a flourishing condition.

In 1872, forty-four mines were at work, nineteen of which

* Blanford, "Memoirs, Geological Survey of India," Vol. III.

turned out upwards of 10,000 tons each *per annum.* At the present time (1879) there are about six principal European companies engaged in the extraction of coal, while many minor firms and native associations contribute to swell the total amount raised.

Formerly a large proportion of the coal was obtained by open workings and quarries: but at the present day most of the seams which were accessible in this way have been exhausted, and regular mining is now carried on with more or less system.* The miners are, however, individually, in some cases allowed a degree of freedom, or rather licence, which would never be permitted in European mines. They chiefly belong to two races, the Bhowries and the Sontals—the former using the pick, while the latter cannot be induced to work with any other tool than a crowbar, with which they produce an altogether disproportionate amount of small coal and dust. The pillar and stall is generally practised in preference to the long-wall system of "getting" the coal. None of the mines are of great depth, and a perfect freedom from fire and choke-damp render it possible to carry on the work without its being necessary to adopt the precautions which in England only too often fail to secure the object aimed at. Many of the seams are of considerable thickness, one which is worked contains nearly forty feet of coal. As a rule, however, the thick seams, especially those in the lower measures, do not contain the best coal. Compared with ordinary English coal, the Ranigunj coals, and Indian coals generally are very much inferior in working power, still they are capable of generating steam in both locomotive and other engines. In 1868 the total amount of coal raised in the Ranigunj mines was 564,933 tons; but in 1872 the total amount was only 322,443 tons.

I quote the following from the resolution on the subject of the Lieutenant-Governor of Bengal for the year 1879:—

> "The year was a prosperous one for the coal companies of Ranigunj. There was a large demand, and production was greatly stimulated. The output is estimated to have been 523,097 tons against 467,924 tons, the average of the three previous years. The number of persons employed was 388,931 men, 194,647 women, and 27,277 children."

The coal, which is fairly representative of Indian coals, may

* Some of the mines are now admirably managed.

be described as a non-caking bituminous coal composed of distinct laminæ of a bright jetty, and of a dull, more earthy, rock.

The average of thirty-one assays* of samples from different mines gave the following results:—

Moisture,	4·8
Volatile,	25·83
Carbon (fixed),	53·2
Ash,	16·17
	100·0

The cost of steam coal at the pit's mouth is from 2½ to 3 rupees, say 5 to 6 shillings. In Calcutta the same coal costs 14 to 16 shillings, and in Lahore about £5.

VI.—JERIAH.†

The Jeriah coal-field is situated in the valley of the Damuda river, sixteen miles west of the Ranigunj field. Its area is about 200 square miles.

The following groups only occur, the highest groups of the Ranigunj field being unrepresented:—

Ranigunj,	2,200 feet.
Ironstone shales,	700 "
Barakar,	3,000 "
Talchir,	900 "
	6,800 "

The thickness and quality of the seams varies a good deal, but there is no doubt, whatever, that this field contains a vast quantity of valuable fuel. One seam has a maximum thickness of sixty-feet. The estimated available coal in this area is 465 millions of tons.

Whether this field will ever be worked depends very much upon the laying out of a new line of railway communication. The exhaustion or partial exhaustion of coal in the Ranigunj area, an event still far distant, may lead to special arrangements for working it.

* *Vide* "Records Geological Survey of India," Vol. I., p. 155.

† Hughes, "Memoirs Geol. Survey India," Vol. V. "Manual," p. 185.

VII.—Bokaro.*

The Bokaro field is situated in the valley of the Damuda, commencing at a point two miles west of the termination of the Jeriah field. Its area is about 220 square miles.

The groups represented in this field are precisely identical with those of the Ranigunj field, namely :—

Mahadeva, ...	—
Panchet, ...	—
Ranigunj, ...	—
Ironstone shale, . . .	1,500 feet
Barakar, ...	—
Talchir, ...	—

Some of the coal seams are of large size, one of eighty-eight feet having been measured. The quality is generally inferior. Still there is no doubt that the field contains a vast store of valuable fuel. The estimated available coal is 1,500,000,000 tons. Except by outcrop workings nothing has been done to develop the resources of this field; owing to its position it is not likely, unless by the establishment of some local industry, that it will ever become available for useful purposes.

VIII.—Ramgurh.†

This field is situated to the south of the Bokaro field in the valley of the Damuda. Its area is 40 square miles.

The following groups only occur as in the case of the Jeriah field; it is uncertain whether the higher groups were denuded or were never deposited :—

Ranigunj, ...	? feet
Ironstone shale, ...	1,200 „
Barakar, ...	3,000 „
Talchir, ...	850 „
	5,050 „

The coal is for the most part of poor quality and limited in extent. There are, however, a good many seams; possibly when opened up they may prove to contain better fuel than any which is now exposed in natural sections. But the field is unfavourably situated with regard to lines of communication.

* Hughes, " Mem. Geol. Survey India," Vol. VI. " Manua 'p. 187.

† Ball, " Mem. Geol. Survey India," Vol. VI. "Manual," p. 190.

IX. AND X.—KARANPURA NORTH AND SOUTH.*

These fields are situated at the head of the Damuda valley. Their areas respectively are 472 and 72 square miles.

The groups occurring are the same as in the Bokaro field, save that in the southern field there has been no trace of Panchets yet discovered:—

Mahadeva,	300 feet
Panchet,	? "
Ranigunj,	? "
Ironstone shale,	600 "
Barakar,	1,500 "
Talchir,	400 "

The following is an assay of a sample of the better class of coals in these fields:—

Carbon,	64·5
Volatile,	27·
Ash,	8·5
	100·0

The estimated amounts of coal are, for the larger field (North Karanpura), 8,750,000,000 tons, the estimated total thickness of seams being 38 feet. In the South Karanpura field the estimated amount is 75,000,000 tons, the thickness being 70 feet.

The situation of these fields, in a deep valley surrounded by hills, renders it improbable that this vast amount of coal will ever become available for economic purposes.

XI.—CHOPÉ.†

This is a small field of less than one square mile in extent. The chief point of interest about it is its position, which is on the Hazaribagh plateau, at an elevation of about 2,000 feet above the sea, or nearly 1,000 above the nearest fields in the valley of the Damuda

The groups represented are the Barakar and Talchir.

There is only one seam of coal, and it is of poor quality.

* Hughes, "Mem. Geol. Survey of India," Vol. VII. "Manual," pp. 191–196.

† Ball, "Mem. Geol. Survey, India," Vol. VIII. "Manual," p. 196.

XII.—ITKURI.*

This field is situated about 25 miles north-west of Hazaribagh. The Barakar coal-measures, which include a few seams of inferior coal, are exposed only over half a square mile. The remainder of the area is made up by rocks of the Talchir group.

XIII.—AURUNGA.†

This field is situated in the district of Lohardugga, to the west of the sources of the Damuda, in the valley of the Koel, a tributary of the Sone. The area is 97 square miles, and the groups represented are:—

Mahadeva,	1,000 feet.
Panchet,	700 „
Ranigunj,	1,000 „
Barakar,	1,500 „
Talchir,	300 „
	4,500 „

There are numerous coal seams, some of large size, the estimated amount of coal which they contain being 20,000,000 tons.

The following average proportions of constituents derived from the assays of seven samples from different localities indicate a very poor quality of fuel.

Moisture,	6·7
Volatile,	29·3
Carbon,	36·5
Ash,	27·5
	100·0

Valuable and extensive deposits of iron ores and limestones occurring in and near the coal field, this inferiority of the coal is to be lamented, as should a project for manufacturing iron there ever be adopted, fuel, it seems probable, will have to be obtained from some of the neighbouring fields.

* Hughes, "Mem. Geol. Survey of India," Vol. VIII., p. 321. "Manual," p. 197.

† Ball, "Mem. Geol. Survey of India," Vol. XV.

XIV.—HUTAR.*

This field lies to the west of the Aurunga, being situated more directly in the valley of the Koel. The area is 78·6 miles, and the following groups occur:—

Mahadeva,	1,000 feet.
(Ranigunj?) Barakar,	2,750 "
Talchir,	300 "
	4,050 "

Data for the estimation of the quantity of available coal are wanting, but there are a considerable number of seams, and the average of eight assays gives the following favourable result:—

Moisture,	5·95
Carbon,	55·35
Volatile,	28·
Ash,	10·7
	100·

XV.—DALTONGUNJ.†

This field is also in the valley of the Koel, district of Lohardugga. The area is 200 square miles. Two groups only are represented, viz., the Barakars and Talchirs, the latter being about 500 feet thick.

Seams of coal are not numerous; one, which has a thickness of about 5 or 6 feet, contains excellent fuel, according to the Indian standard, as the following average of four assays, amply testifies:—

Moisture,	3·45
Volatile,	21·05
Carbon,	64·8
Ash,	10·7
	100.

The estimated total of available coal is 11,600,000 tons.

This field has been worked to a small extent from time to time. There is some prospect of its being now opened up in connexion with the Sone-river canal system.

XVI.—TATTAPANI.‡

Besides a few notes by myself, the result of a day devoted to the examination of its eastern frontier, nothing is published yet

* Ball, "Mem. Geol. Survey of India," Vol. XV.

† Hughes, "Mem. Geol. Survey of India," Vol. VIII.

‡ Ball, *id.*, Vol. XV.

regarding this field, but a detailed account is, I understand, about to appear. The formations found in the Aurunga Field all occur there, and there is some coal. On the southern faulted boundary there is a remarkable series of hot springs, from which the locality has received its name Tattapani (boiling water).

XVII.—South Rewah and Sohagpur.*

This is a wide tract in the Sone Valley, covering perhaps 8,000 square miles. The geology is imperfectly known; it is probable that nearly all the recognized groups of the Gondwana formation are represented within the area. Coal occurs, but little yet has been ascertained as to its average quality and total amount.

XVIII.—Jhilmilli.†

This is a small area of about thirty-five square miles, which has not yet been fully examined. Besides Talchir and Barakar rocks one or more of the younger groups are represented.

Coal seams of some promise have been observed in the Barakars. Traces of coaly matter, forming a seam of six inches, were also discovered in the Talchirs, a quite exceptional circumstance.

XIX.—Bisrampur.‡

This field occupies the central basis of Sirguja at an elevation of about 1,800 feet above the sea. Its area is about 400 square miles. The formations met with are—

Mahadeva, ...	1,000 feet
Barakar, ...	500 „
Talchir, ...	200 „

A large number of coal seams have been discovered, some containing good coal, but, so far as is at present known, they are not of great promise. This is of less importance since the locality is so landlocked that it is never likely to be the scene of mining operations.

XX.—Lukanpur.§

This field lies to the south of the Bisrampur area, from which it is separated by a fault and a belt of Talchirs, with inliers of

* "Manual," Vol. I., p. 201. † "Manual," Vol. I., p. 204.

‡ Ball "Records Geological Survey of India," Vol. I., p. 205.

§ Ball, MS. Notes, "Manual," Vol. I., p. 206.

metamorphic and sub-metamorphic rocks. Its total extent has not yet been ascertained, but it is probable that it is continuous with a large area of coal measure rocks, believed to exist far to the westward.

Several seams of coal have been discovered, one of which is five and a half feet thick and contains good coal. The rocks belong to the Barakar and Talchir groups.

XXI.—RAMPUR.*

This area adjoins the last on the north, and is probably more or less connected with that which follows, but it is partly situated in a different catchment area, near the sources of the Rer river a tributary of the Sone, while the field about to be described is wholly within the limits of the Mahanadi basin. The rocks of this portion consist of Mahadevas, Barakars, and Talchirs. No good coal has been observed yet. The most remarkable seam is situate at the base of the massive square block of Mahadevas known as the Ramgurh Hill.† Above it issues a perennial fountain of water, which, with some other peculiarities, has caused the spot to be regarded as one of great sanctity by the natives.

XXII.—RAIGURH AND HINGIR.—UDAIPUR AND KORBA.

These places are situated in a wide extent of coal measures and associated rocks, which cover an area of not less than 1,000 square miles. The country is very wild and difficult of access, and our knowledge of the field is as yet imperfect. Especially this is the case as to the identity of the rocks younger than the Barakar coal measures. There appear to be two distinct groups, one containing fossil plants which serve to correlate it with the Kamthi-Ranigunj group, the other being probably of Mahadeva age, but, owing to the great similarity in lithological characters, separation has been attended with great difficulty and uncertainty.

The coal seams are sometimes of enormous size, thicknesses as great as ninety feet, and even 168 feet, having been measured,

* Ball, MS. Notes, "Manual," Vol. I., p. 207.

† "Jungle Life in India," p. 324.

‡ Blanford, "Records G. S. I.," Vol. III., p. 54. Ball, *id.*, IV., pp. 101, 107; VIII., pp. 102, 121; and X., pp. 170, 173; "Manual," pp. 206, 210.

but, although containing good coal, these are often largely made up of carboniferous shale, which is incapable of supporting combustion.

In one locality, the Samarsota River, the coal seams have been greatly disturbed, being bent into an anticlinal at the crest, of which the lowest rocks of the area are exposed.

Should a direct line ever be made, connecting Calcutta with the Central Provinces, this field will doubtless be opened up, and may, in that contingency, become of great importance.

ORISSA.

XXIII.—Talchir.*

The Talchir coal field is situated in the valley of the Brahmini, which may be regarded as a tributary of the Mahanadi, since it anastomoses with it in the conjoined deltas. The field is really the south-eastern extension of the last-mentioned area, the separation being inconsiderable.

The area is about 700 square miles in extent.

The groups represented are similar to those found in the last area, and have the following estimated thicknesses :—

Mahadeva, Kamthi, }	1,500 to 2,000 feet.
Barakar, ...	about 1,800 ,,
Talchir, ...	500 ,,

The Talchir group received its name from this locality, where it was first discriminated.

The coal is of inferior quality, one large seam being similar in character, as it is largely made up of carbonaceous shale, to that described above in Hingir.

The demand for coal in Orissa is too limited to render it probable that under present conditions of communication the field will ever be of much value.

Further to the south-east, near the town of Cuttack, there is an area of sandstones and conglomerates in which fossil plants of the Rajmahal type occur.

* Blanford and Theobald, "Mem. Geol. Survey of India," Vol. I., pp. 33, 38. Ball, "Records," Vol. X., pp. 170, 173, and "Manual," Vol. I., p. 210.

SATPURA BASIN.*

The Satpura region, so called from one of the ranges of hills consists of a hilly tract separating the valleys of the Narbada and Tapti rivers.

It is difficult to speak of this area as a single expanse of coal measures, since, as a matter of fact, these only appear at intervals under the margins of younger groups, covering a wide extent of country which stretches for a distance of about 170 miles. Accordingly, the dimensions of the basin vary much as estimated by different authorities.

About 2,000 square miles appears to be a safe minimum, but besides this it should be remembered that there is a considerable tract in which the underlying formations are concealed by the Tertiary Dekan traps, and a large area towards Jabalpur, in which no coal measures have been proved to exist under the younger formations which prevail there.

In this region the several groups of the Gondwana system are developed to their maximum extent. They have been named and classified by Mr. H. B. Medlicott as follows:—

	Upper Gondwana.		
	Jabalpur Group		1,000 feet.
Mahadeva Series,	Upper—Bagra,		800 „
	Middle—Denwa,		1,200 „
	Lower—Pachmari,		8,000 „
	Lower Gondwana.		
Damuda Series,	Upper—Bijori,	Group	4,000 „
	Upper—Motur,	„	6,000 „
	Lower—Barakar and Karharbari,	„	500 „
	Talchir,	„	1,000 „
			22,500 „

It is not contended that this enormous thickness of rocks was ever successively deposited in vertical order in any one locality. The figures are to be taken as the maxima of the deposits of successive periods.

The principal localities where coal measures occur, are near Mopani, and in the valleys of the Tawa and Pench rivers, the former is on the northern boundary.

* J. G. and H. B. Medlicott, "Memoirs Geological Survey of India," Vol. II., pp. 97, 267; X., pp. 133, 188. "Records Geological Survey of India," Vol III., pp. 63, 70, and VIII., pp. 65, 86.

XXIV.—Mopani.*

This field is one of high importance, in consequence of its position with reference to the railway. It is situated 95 miles (by rail) W.S.W. of Jabalpur, and 322 miles from Allahabad, or 83 miles nearer than the Karharbari field to the same place.

The area in which coal has been proved to exist is small, though recently an important addition appears to have been made. The old area is much cut up by faults, and the largest seam has been destroyed by fire. The seams are :—

1. Inferior coal, ...	12 feet not worked.	
2. Good cooking coal, ...	18–20 feet, on fire.	
3. Good "	3 feet 4 inches.	worked together.
4. 10 feet good "	12 feet	

These seams are and have been worked for many years by the Narbada Coal and Iron Company. In 1874, the out-turn ranged from 700 to 1,000 tons per month. It was sold to the railway company at about ten rupees, or at from three to four times the price of Ranigunj and Kaharbari coals. It could command this price in consequence of the cost of carriage respectively of Kaharbari and of English coal from Bombay.

In 1878, the average cost of Kaharbari coal on the line between Jabalpur and Allahabad amounted to £1 2*s.* 4¾*d.* per ton.

XXV.—Tawa.†

The coal seams of the Tawa Valley are of no great promise; they are of irregular thicknesses, and the coal is generally inferior.

XXVI.—Pench.‡

There are many seams in this area, some of which are of considerable thickness, and the coal is often of fair quality. The position of the field, surrounded by hilly country, renders it improbable that it will ever be of much commercial value.

* Medlicott, "Memoirs Geological Survey of India," Vol. II., 1859; Vol. X., 1873. "Records," Vol. III., 1870; Vol. IV., 1871; Vol. V., 1872; Vol. VIII., 1875; Vol. XII., 1879.

† "Manual," Vol. I., p. 218. ‡ l.c.

GODAVERI VALLEY.

XXVII.—BANDAR.*

This field is situated near the village of Chimur, thirty miles N .E. of Warora, in the Chanda district. The existence of coal measures under a small tract of Kamthi beds, 5 to 6 miles square, has been proved by boring. Three seams of coal have been ascertained to exist, and these have a maximum total thickness of 38 feet. The coal is similar in character to that of Warora.

XXVIII.—WARDHA OR CHANDA, &c.†

This coal field constitutes the northernmost extremity of an immense tract of Gondwana rocks, which extend for about 285 miles from north-west to south-east in the valleys of the Wardha Pranhita, and Godaveri basins.

The groups of rocks exposed are as follows:—

	Upper Gondwana.	
Kota Maleri,	1,500	feet.
Kamthi,	2,500 to 3,000	,,
Barakar,	250	,,
Talchir,	500	,,

Any attempt to give an idea of the distribution of coal measures throughout this area, without employing a mass of detail unsuited to this paper, would certainly fail. I shall therefore confine myself to quoting Mr. Hughes' estimate of the amounts of coal, in several of the particular tracts, where its existence has been proved by actual outcrops or by borings.

	Actual Quantity. Tons.	Amount available. Tons.
Warora basin,	20,000,000	14,000,000
Ghugus,	90,000,000	45,000,000
Wun,	2,100,000,000	1,500,000,000
Between Wun and Papur,	105,000,000	50,000,000
Between Junara and Chicholi,	150,000,000	75,000,000
Sasti and Paoni basins,	60,000,000	30,000,000
	2,525,000,000	1,714,000,000

* Hughes, "Memoirs Geological Survey of India," Vol. XIII., pp. 145–154; "Manual," Vol. I., p. 226.

† Hughes, l.c., pp. 1–145.

The following assays will serve to convey some idea of the quality of the coals:—

	Warora.	Pisgaon.	Ghugus.*
Fixed Carbon,	45·4	65·1	45·61
Volatile Combustible,	26·5	19·2	33·49
Water,	13·9		
Ash,	14·2	15·7	20·90
	100·	100·	100·

In Mr. Hughes' "Memoir," assays of samples from other localities are also given.

The Warora coal is deficient in fixed carbon, a larger per-centage of which is essential where great heating power is required. It also is deficient in combustible volatile gases. Pisgaon coal, however, contains a more considerable proportion of fixed carbon, viz., 65·1 per cent.

The only pits in this wide area, which are worked, are at Warora, where the out-turn was, in 1878, 1,500 tons per week.

The great outlay by the Government in connexion with the exploration and testing of the field† has not yet been nearly repaid, the cost of extraction being heavy.

A special branch line conveys the Wardha coal to the Nagpur branch of the great Indian peninsular railway, by means of which it is distributed both for use on this line and in factories.

Several other small areas of coal-bearing rocks occur further down the course of the Godaveri valley at Dumagudium, Mudavaram, &c., &c., to which much interest has attached, as it was hoped that they might yield a supply of coal for the Madras Presidency, but the prospect of their doing so does not appear to be a good one.

XXIX.—Kamaram.‡

This name has been given to two small fields situated near the village of Kamaram, which lies forty miles a little north of east from Warangul in the Hyderabad territory.

The larger one is six miles long, by about one mile broad; it consists of Talchir, Barakar, and Kamthi rocks. It includes two coal seams of fair coal, measuring respectively 9 feet and 6 feet. The available coal is estimated at 2,265,120÷2

* Average of sixteen assays.

† £600,000 is stated to have been already expended at Warora alone at the time Mr. Hughes' report was printed.

‡ King, "Records Geological Survey of India," Vol. V., p. 50. "Manual," Vol. I. p. 240.

or 1,132,560 tons, and it is stated to be equal to the average coal of the Wardah fields. Its position is unfavourable to its development, water carriage being too far distant.

The smaller field, which is about half a square mile in area, is of no importance.

XXX.—SINGARENI.*

This field is situated near the village of Singareni in the Hyderabad territory, about thirty miles to the south-east of the Kamaram Field. Its area is nineteen square miles, the coal measures being found throughout about eight square miles. The groups represented are Kamthis, Barakars, and Talchirs. One coal seam was discovered, but being much concealed, its thickness was not ascertained; an assay of a sample from it gave:—

Fixed Carbon,	62·4
Volatile,	22·6
Moisture (6)	
Ash,	15
	100·

Additional seams, one of them 21 feet thick, have since been proved by boring.

This field may possibly become of some economic importance, as there is a prospect of there being a railway constructed at no great distance from it.

SIKKIM.

XXXI.—DARJILING DISTRICT.†

This field occupies a narrow zone, which stretches along the foot of the Himalayas, from Pankabari to Dalingkote. The rocks are probably Barakars, which have been much crushed and tilted, dipping at angles of from 40° to 90° to N.N.E., or towards the main mass of the hills. Frequently the sandstones have been converted into quartzites, and the shales into splintery slates. Much of the coal is in the condition of powder, and some of it has assumed the character of graphite. The effect of the compression has been to reduce it by removal of the volatile portions to the condition of an anthracite. Some experiments were made with a view to

* King, *loc. cit.*, p. 65. "Manual," Vol. I., p. 241.

† Mallet, "Memoirs Geological Survey of India," Vol. XI. "Manual," Vol. I.

utilizing it in the manufacture of artificial fuel, but the process found to be requisite was too expensive, and the difficulty of boring in these crushed rocks is so great as to render it improbable that this coal will ever be commercially available.

One seam is 11 feet in thickness. The average of five assays of the coal gives the following composition :—

Carbon, ...	70·66
Volatile, ...	9·20
Ash, ...	20·14
	100.

Into a description of the complicated geological relations of these beds with those forming the adjoining mass of the Himalayas, I do not now propose to enter. Mr. Mallet has arrived at the somewhat startling conclusion that the coal measures are younger, and underlie the highly metamorphic rocks of the outer slopes. To do justice to his arguments would require more space than is at present available for the purpose.

The fact that this locality is the only one north of the Ganges where Gondwana rocks occur, is of great interest in connexion with any discussion as to the early relations which existed between the Peninsular and Himalayan regions, and indeed the formation of the Himalayas themselves.

ASSAM.*

Five distinct coal fields exist in the valley of the Bhramaputra, in the province of Assam, They are distinguished by the following names :—XXXII. Makum; XXXIII. Jaipur; XXXIV. Nagira; XXXV. Janji; XXXVI. Disai. It will be convenient in this abbreviated account to treat of them collectively.

Some uncertainty exists as to the age of the rocks, but the balance of evidence seems to favour the view, that it is middle Tertiary (Miocene), and therefore distinct from the Cretaceous and Nummulitic coals of the Khasi hills.

The coal differs from that of the Indian coal fields in having a

* Mallet, "Mem. Geol. Survey of India," Vol. XII., pt. 2. "Manual," Vol. II., p. 701.

homogeneous structure, and in the absence of a laminated structure the average of the assay of twenty-three samples gave :—

Moisture,	5
Carbon,	56·5
Volatile,	34·6
Ash,	3·9
	100·

This is a high quality of fuel as compared with Indian coals.

The opening up of these fields is a point of the highest importance, since at present coal is carried 1,000 miles from Bengal for the navigation of the Bhramaputra, this causing a ten-fold increase on the prime cost.

It is possible that some of the coal of the Khasi hills above alluded to, may prove of value; but the same does not seem probable in reference to the Tertiary coals of the north-west provinces, although hopes in that direction have often been expressed, and a project for the exploration of one of these deposits has, I understand, recently assumed a tangible form, a company having been formed, the results of whose operations will be watched with interest.

PRESENT OUT-TURN OF COAL IN INDIA, AND IMPORTATIONS OF COAL FROM FOREIGN COUNTRIES.

A very interesting paper on the coal importations into India by Mr. Hughes, of the Geological Survey, was published in the year, 1879.* I quote from it the following general remarks, but must refer to the original tables for details:—

"Beginning with the year 1853, the shipments of coal and coke to India were 43,562 tons. Since then, after the lapse of a quarter of a century, they have risen to 609,735 tons. The ratio of increase has not been by any means steady; wars, rumours of wars, famines, and improved home freights have always exercised an irregular influence; as during the past two years, the importation having jumped from 399,887 tons in 1876 to 539,533 tons in 1877, and to 609,735 tons in 1878. Our main supply has hitherto been derived from the United Kingdom; the contributions furnished by other countries, with the exception of Australia and France, during spasmodic periods, being insignificant."

Australian coal has been imported since 1857, but the amount has fluctuated much from year to year; in 1858, 14,061 tons went

* "Records of the Geological Survey of India," Vol. XII., p. 83.

to Bengal, and 8,998 to Bombay. In 1874, 14,677 tons went to Bengal, and apparently none to Bombay. In 1877, only 799 tons went to Bengal, and none to Bombay, so that the trade is probably coming to an end.

As Bengal has her own coal, she imports less than Bombay,* the returns being :—

	1870.	1877.
Bombay,	239,651	368,937
Bengal,	42,433	76,278
Burmah,	20,198	47,770
Madras,	11,648	22,544
Sind,	1,995	7,855
	315,935	523,384
Add coke,	21,088	16,149
	337,023	539,533

That a certain amount of foreign coal will always be in the Indian market is certain, since owners of outward bound ships find it convenient to make use of it as ballast, and carried in this way it is sometimes sold at very low prices; thus, on one occasion English coal was quoted in the Calcutta market at sixteen shillings a ton, and it seldom, I believe, rises to much above £2 a ton. The trade in Indian coal between Calcutta and Bombay by sea is not yet fully developed, and it is uncertain whether it will ever assume such dimensions as seriously to affect the imports of foreign coal into Bombay.

In conclusion it may be said that the annual consumption of coal in India, for sea-going and river steamers, railways, factories, domestic and other purposes, amounts to upwards of one million tons, and that, in round figures, one half of this amount is raised in the country, and the other imported.

* I have (p. 251 *supra*) intimated that there is a varying point on the railway where Bengal coal meets coal imported into Bombay at equal prices, their relative values as fuel being taken into consideration.

Note on the Map.

The map given in "Jungle Life in India," serves to indicate the positions of the principal Bengal and Central Provinces coal fields. Some of the outlying portions of the latter and the Sikkim and Assam fields are not included. For their positions reference should be made to the map published with the Manual of the Geology of India.

XXIX.—ON THE MODE OF OCCURRENCE AND DISTRIBUTION OF GOLD IN INDIA, BY V. BALL, M.A., F.G.S., GEOLOGICAL SURVEY OF INDIA, HON. SEC. ROYAL GEOLOGICAL SOCIETY OF IRELAND.

[Read 19th May, 1880.]

The first remark which I would make is, that I have somewhat modified and generalized the title of this paper, as in the original form the reference to "recent discoveries in the Madras Presidency" was, perhaps, calculated to mislead. Though there have been recent most important researches in connexion with the occurrence of gold in Southern India, so far as I know, they cannot strictly be described as new discoveries. There is the most complete evidence that gold has not only been long known to exist, but that it has been worked and sought for in these regions from a very distant period.

The subject of Indian gold is one of vast extent. Not only does the precious metal occur under varying circumstances over a wide area of country, but the methods of extraction practised by the natives seem to have originated long before the Christian era, and the out-turn gradually accumulated through long periods of time even by such imperfect operations, may not impossibly account for the great stores of gold which, according to historians, were undoubtedly possessed by the Rajas in some parts of India formerly.

Thus there may be said to be two wholly distinct aspects of the question: I. The Geological. II. That which belongs to the province of the Antiquarian, Historian, and Political Economist. It will be possible for me to allude only very briefly to the second aspect, since not only are many of the necessary works of reference inaccessible to me at present, but also because such a topic requires the hand of a specialist in that kind of inquiry for its adequate treatment.

The ultimate derivation of the gold throughout India is chiefly from the quartz veins which occur in the different series of more or less metamorphosed rocks which are recognized as existing in that country. I say chiefly because I have reason to believe that in some localities gold is contained in certain chloritic schists, and possibly, too, in some forms of gneiss. Proximately

it is occasionally derived from rocks belonging to various formations which range from Permian through Tertiary periods up to recent alluvial deposits. To some of the facts under this last heading, which will be found in the following detailed accounts, I would invite particular attention, as they are of considerable interest when placed in comparison with similar facts in other gold-producing countries.

Gold washing, as practised in India, affords an example, I believe, of human degradation. The colonies of washers who are found plying their trade in most of the areas where, geologically speaking, the occurrence of gold is possible, must be regarded as the remnants of a people possessing special knowledge*; for although the former may have some acquaintance with the appearance of the rocks in the neighbourhood of which gold occurs, still, so far as I could ascertain from a close examination of the operations of two gold washers who were in my service for about three months, such acquaintance, if possessed, is rarely availed of. Indeed I doubt if they ever look upon the rocks as being really the source from whence the gold has been derived. They know of its occurrence in the sands and alluvial soils, but whence it ultimately came from they do not trouble to consider.

But it cannot always have been so, for their earliest progenitors must have ascertained the existence of the gold by the application of experimental research in localities where, from theoretical considerations, they believed it to exist.

It is scarcely possible that the non-gold-producing areas in which the Dekan trap or basalt and the rocks of the Vindhyan formation prevail, and which aggregate a total area of about one-fourth of the peninsula, were ever systematically prospected, and for this reason, if for no other, that the washers, if they were comparable to those of the present day, could not have devoted months and years to the exploration of, for them, barren tracts, simply from the fact that they could not subsist under such circumstances.

By what means, soever, they were led to select and settle in

* I have often been struck with the traditional knowledge of such subjects as *Materia medica* possessed by individuals of semi-savage tribes who never seem to discover a new idea for themselves, nor to modify in the slightest degree, when uninfluenced by superior races, their methods of performing any one single act in their domestic economy.

these gold-producing tracts, it is certain that within such limits a process of segregation has been going on towards the richest points.

In a part of Western Bengal * I found that generations of washers had demarcated limits within which washing was remunerative, and these limits corresponded in a striking degree to the well-defined boundaries between two formations—the metamorphic and the sub-metamorphic. In the area occupied by the former, gold was not absent; but its abundance, as contrasted with that in the latter, I ascertained, by two independent methods of calculation which are described below, was in the proportion of 1 to 3. Hence, as the washers only managed to eke out a bare subsistence in the sub-metamorphic area, they confined their operations to it.

The detailed accounts of Indian gold-producing tracts admit of the following geographical arrangement, proceeding from South to North :—

Madras.

1. Wynaad, and 2. Kolar.

Bombay.

1. Dharwar, 2. Belgaum, and 3. Kaladgi.

Bengal.

1. Central Provinces, 2. Orissa, 3. S. W. Bengal, 4. N. W. Provinces, including Himalayas and Punjab.

Ultra-Peninsular Areas.

1. Assam, 2. Burmah, 3. Afghanistan, 4. Thibet.

MADRAS.

Wynaad District.—The recent contributions to the literature of the gold fields of the south-eastern portion of the Wynaad are so voluminous that I experience a difficulty in preparing a sufficiently complete epitome of their contents. Among these contributions the principal are the reports by Mr. Wm. King, jun., † Deputy Superintendent of the Geological Survey of India, and Mr. Brough Smyth,‡ who was specially deputed by the Government of India to explore and report upon the gold in Southern India.

* *Vide infra*, p. 537.

† Records of the Geological Survey of India, Vol. VIII., p. 29, and Vol. XI., p. 235.

‡ "Report on the Gold Mines of the South-Eastern portion of the Wynaad."

The Wynaad forms a terrace of mountain land intermediate in position between the low country of Malabar and the lofty plateau of the Nilgiri Mountains. It is separated into three portions, which are locally known as North, South, and South-East Wynaad; the latter portion has recently been transferred from the official limits of the Malabar jurisdiction to those of the Nilgiri District, and in it the principal gold tracts are situated.

The principal rocks of the area are granites, gneisses, and other forms of metamorphic rocks which are traversed by numerous quartz reefs.

In the tract to which Mr. Brough Smyth gave his particular attention, and which covers about 500 square miles, 200 outcrops, not necessarily distinct reefs, were counted; they are, in short, stated to be more numerous and proportionately wider and richer than in almost any part of Australia. Mr. King, first, and subsequently Mr. Brough Smyth, pointed out that throughout the area there are no accumulations of drifts or deep leads covered by volcanic formations, such as characterise the Australian fields. Operations, therefore, have been hitherto, and must be in the future, confined to "surfacing" and quartz mining, a regular hydraulic system of mining being inapplicable.

By all the authorities it is considered that the native processes of washing, as practiced to-day by the Korumbas and Moplas, is of high antiquity, dating so far back as 500 years B.C. There is evidence, however, that operations were not limited to mere washing, but that mining was carried on by one or more classes of people who have no representatives at the present day. Mr. Brough Smyth enumerates the traces of this higher skill under the following heads:—

1. Quarrying on the Outcrops of the Veins.
2. Vertical Shafts.
3. Adits.
4. Vertical Shafts with Adits.
5. Shafts on underlie.

And remarks that they show different degrees of knowledge of the miner's art.

The vertical shafts though not considered to afford evidence of the highest degree of mining skill offer a problem difficult of

solution. They are, even when in solid quartz, sometimes 70 feet deep, with smooth sides and quite plumb; what the tools were which enabled the miners to produce such work in hard, dense, quartz, no one appears to be able to suggest. The fragments of stone obtained from these various mines were pounded with hand mullers, the pounding places being still seen, and the pounded stone was then, it is believed, washed in a wooden dish and treated with mercury.

The Korumbas or gold washers, who are admitted to be skilful, do not regard the gold as being derived from the reefs, though they generally select spots near the reefs for washing. Their earnings amount to from two to three annas (*3d.* to *4½d.*), a day but it is possible that at an earlier period of the industry it may have been more profitable, since Mr. Brough Smyth says that the present condition of the country is, that it is covered with 'tailings,' and corresponds to that of an abandoned Australian washing. Still it is the case that:—

"On washing a few dishes of the surface soil anywhere a few streaks of very fine gold will be found. In the vicinity of the reefs rather heavy gold is got by sluicing; and if a suitable spot be selected the native miners will obtain, even by their methods, sufficient gold to remunerate them for their labour."

I cannot quote here a tithe of the evidence which exists as to the former wealth of Southern India; but the following extract from a letter by Mr. E. B. Eastwick will be read with interest. Mr. Eastwick quotes from Dr. Burnell:—

"It has always been a puzzle whence the great wealth came which enabled the Rajahs of Southern India to construct enormous works, which collectively must have cost millions. The marvel is increased by the fact that so far from these Indian princes having been impoverished by this expenditure, they were still possessed of vast treasures which fell into the hands of the Moslems in the fourteenth century, and were carried away to Delhi. The famous Tanjore Temple inscription speaks of a great abundance of gold which can only have arisen from mines. Dr. Burnell writes:—'It proves that in the eleventh century gold was the most common precious metal in India. Silver is little mentioned and it thus appears that the present state of things which is exactly the reverse, was only brought about by the Portuguese in the sixteenth century. I submit that the great abundance of gold spoken of in the inscription can have arisen only from mines, and that in the terrible convulsions caused by the irruption of Moslem invaders from the north, and Europeans from the West, the position of these gold fields was lost sight of.'"—*Times*, January 2nd, 1879.

The History of Tippoo Sultan further gives definite accounts of vast hoards of gold.*

To my mind, as an occasional visitor to the Madras Presidency, there is a noteworthy and remarkable fact which seems to have been overlooked by writers on this subject, and that is that the total amount of gold in the possession of the poorer classes of the inhabitants of Southern India must be enormous, and proportionally much greater than in other parts of the country. Men, women, and children even of the coolie class are commonly to be seen wearing ornaments of pure gold. The nose ornaments are worn almost universally by the women and children. In the northern parts of India the ornaments which are worn are generally made of the baser metals or of glass, &c. In times of famine or distress in Southern India these golden ornaments are disposed of in order to procure food. Throughout India the use of jewellery by the higher classes is sufficiently notorious not to require special comment; but the use of pure gold by the lower orders is in a great measure, I believe, peculiar to Madras.

In the year 1831, the Government appointed a Commission to make inquiries into the gold-yielding district of the Wynaad, but the matter was for a time allowed to drop. During the last decade, however, largely in consequence of the number of Europeans attracted to the Coffee Plantations, interest in the subject was again aroused, and several Pioneer Companies were formed, but although favourable per-centages were obtained by assays the practical results of quartz crushing were counted only in pennyweights per ton, and owing to defective management and imperfect machinery, the time expended, and consequently the cost of production proved greater than the receipts.

Mr. Brough Smyth has clearly demonstrated that if proper care be taken under skilled management the working of gold in Southern India must become a most profitable undertaking:—

"The average yield out of 137 samples assayed was 2 oz. 13 dwts. and 2 grains per ton, or if one exceptional sample, which yielded 204½ oz., and another which gave 25½ oz. to the ton be left out, the average yield was 1 oz. 8 dwts. 22 grains per ton."

* It may be well to point out that gold working in these early times was in all probability carried on by slave labour, or what amounted very much to the same thing, and that peculation met with pretty summary treatment. In these modern days peculation will not be restrained by any such deterrents, and that it will be rampant must be expected by those who employ natives.

At the present time there are two or more companies in London, one in Glasgow and several in India, which have for their object the working of mines in the Wynaad, and it is said that already favourable news has been received of the preliminary operations, and the shares are now quoted at a high premium.* As I ventured to predict in my recently published work, "Jungle Life in India," when speaking of mining enterprise generally in India, some of the undertakings seem destined to be hampered seriously on the threshold of their operations, by vexatious litigation which is in part due to the absence of definite mining laws in India.

The following which I extract from the *Pioneer Mail*, of the 22nd April last, is the very latest information I have received on this subject:—

"Since public interest in the gold mining prospects of Southern India waxes stronger day by day, both at home and in this country, and men have made up their minds that the development of vast mineral wealth is merely a question of time, capital, and machinery, it is discouraging to hear that enterprise is likely to be checked in certain parts of the Wynaad in consequence of litigation. This has been anticipated for some little time. It was known that the right of ownership of certain blocks was challenged, and that the dispute was likely to culminate in legal hostilities. It is now currently reported that the 'fat is in the fire,' and that actions and cross-actions are pending. If this rumour prove true, work will, of course, be brought to a deplorable stand-still, and the general high opinion formed of the field at home will suffer. Nothing could exercise a more deterrent effect upon the minds of English speculators than to hear that the legal title to the land was doubtful. For this, and indeed for every reason, the best endeavours will no doubt be made to settle ground-right disputes by arbitration, and to preserve 'peace with honour' among the various claimants."

I am tempted to add the following extract from the *Pioneer* also, which illustrates the shortsighted policy of the native landholders, and the manner in which they can in India—unrestrained by such regulations as exist to limit the powers of landed proprietors in Australia—effectively cripple mining enterprise:—

"The Ootacamund paper learns that 'the Nellambur Rajah is determined to make those who want the mining rights on their coffee estates pay well for them, and all this comes out of the Alpha lease having been extended, for a large sum of money, some Rs. 10,000, for ten acres.

* Extract from William Abbott's Monthly Price List, dated 6th May, 1880. Indian Glenrock Gold Mine—Capital £100,000, Share £1; Paid all; Price £1⅜-1⅝. South Indian Gold Mine—Capital £100,000, Share £1; Paid all; Price £1¾-2.

of land, the vein stone of which, it is expected, will be worked out before the present lease, some eighty years more, expires. It appears also that the mining concessions lately acquired by the Trustees of Messrs. W. Nicol and Co., limits them to the selection of fifty acres within a certain area of his territories, and that owners of estates within these boundaries are not to be interfered with. The Rajah has offered to grant mining rights to all desiring them, but upon terms which will simply drive away capitalists. We certainly think a deputation of the Rajah's tenants should wait upon His Highness and impress upon him the folly of demanding such exorbitant and prohibitive rates, or making them sign agreements which can never be fulfilled.'"

The question of climate is by no means an unimportant one and has not been overlooked by Mr. Brough Smyth. It is a factor known to exercise an appreciable influence in all commercial undertakings in India, as for instance, the cultivation of tea in Assam:—

"Though the climate of the Wynaad has been represented as unhealthy, it is not uncommon for Europeans employed in connexion with coffee gardens, to remain in the district with their families throughout the whole year. Fever is prevalent in March, April, and May, and some of the residents become seriously ill. But it must be borne in mind that a coffee planter who attends carefully to his business is subjected to exposure to the sun during the hot months, and to the heavy rains during the monsoon. He has to walk or ride for many hours each day, when the solar radiation is at its maximum, and during the monsoon his clothes are rarely dry."

KOLAR (OR COLAR) DISTRICT.—The Kolar district situated in Mysore, is also at the present moment attracting a considerable amount of attention in connexion with its gold. Unlike the Wynaad it does not appear to have been as yet systematically explored by any geologist or mining expert, and my information regarding it is therefore limited to what I have been able to collect from notices in the Indian newspapers. However, the general fact is known that the rocks are similar to those of the Wynaad belonging to the metamorphic series, but as to the abundance of quartz reefs I have no information. As in the Wynaad, gold has long been sought for by the natives in Kolar, and it is claimed for this area that it was largely instrumental in supplying the wealth of Southern India spoken of above. Indeed it is stated that Hyder and his son Tippoo erected their mints, the ruins of which are to be seen to this day, in the district close to the spot where the Ooregaum company are at present working. The climate is said to be good—quite equal to that of

Bangalore, the elevation being 3,800 feet above the sea, and the arrangements made by the Government for leasing the land are described as being favourable to enterprise. The following extract is from the *Pioneer* of the 29th April, 1880 (quoting the *Bangalore Spectator*):—

"GOLD MINING IN MYSORE.—From a notice issued by Messrs. Arbuthnot and Co., it appears that a company is being formed to work a portion of the land in the gold-yielding region of Ooregaum in the Kolar district. The Ooregaum company is now hard at work, and the analysis of quartz from its mines, by Mr. Brough Smyth, show conclusively that the auriferous yield is exceedingly good, and that the results to be obtained are all that can be desired. The gold-fields are not far from the Kolar Road Station (six miles) and have everything in their favour—climate as good as Bangalore, food and labour cheap and plentiful, and there is every reason to believe that the gold-mining industry will be a great success in the Mysore country. Those who wish to invest in a good speculation have now such an opportunity placed within their reach, while the well-known name of Messrs. Arbuthnot and Co., is a sufficient guarantee that the Madras Gold Mining Company will be carried on properly. Judging by our English contemporaries, it would appear that there will be no difficulty in alloting the whole of the shares in the London market, where the gold mining companies are highly thought of as safe investments."

BOMBAY.

Within the limits of the Bombay presidency the districts of Dharwar, Belgaum, and Kaladgi are the principal in which gold is known to exist, and where native gold-washers, locally called *Jalgars*, derive a livelihood from searching the auriferous sands.

DHARWAR DISTRICT.—In a paper entitled "The Auriferous Rocks of the Dambal Hills, Dharwar District,"* Mr. R. B. Foote, F.G.S., of the Geological Survey of India, has given an account of his researches when tracing the sources from whence the alluvial gold of the region has been derived, together with a description of the system adopted in washing for gold in the streams which flow through the auriferous tracts.

Mr. Foote considers that the gneissic rocks of this area belong to three distinct series, each characterized by certain lithological peculiarities. He distinguishes them by the following local names:—1. Dhoni; 2. Kappatgode; 3. Soortoor—

"All the streams said by the natives to be auriferous, rise within the limits of the tract occupied by the Soortoor series, and the upper course

* "Records Geological Survey of India, 1874," Vol. VII., p. 133.

of the Soortoor Nullah, the richest of all lies entirely within the area occupied by the pseudo-diorite and associated chloritic schists.

"Quartz reefs occur in all the rock series above enumerated; but those lying within the limits of the Soortoor series are the best defined." . . .

"The surface of the principal reefs has been much broken up, doubtlessly by gold seekers."

Mr. Foote obtained a trace of gold in a fragment of quartz from the principal reef in the Kappatgode series.*

BELGAUM DISTRICT.—Mr. Foote (*l. c.*) mentions several localities in this district where gold was formerly washed for, or was reported to occur in the sands of various streams. It appears to have been derived from quartz reefs which traverse some chloritic schists and pseudo-diorite. In certain localities gold is still obtained in small quantities, but the district does not appear to be one of much promise.

The gold washers (Jalgars) are stated to be Mahomedans, which is exceptional; probably they are converts.

KULADGI DISTRICT.—In reference to this district Mr. Foote† has written:—

"Gold is found in very small quantities in some of the streams flowing into the upper part of the Malprabba, from both sides, through a region occupied by chloritic schists, with rather poor hæmatite schist intervening.

"The exact source of the gold supply remains to be determined. The yield is so exceedingly small that these streams are now but very rarely visited by the Jalgars or gold washers. Very few quartz veins occur in this region, and none were noticed with a north to south course. A small stream a little westward of the village of Belowaddi appears to be the most auriferous, but I failed in getting an appreciable quantity of gold in a number of carefully selected samples of sand and gravels collected in promising places in the bed."

BENGAL.

Using the term Bengal in its widest acceptation, the gold-producing areas included in it may be classified as follows:—

1. Central Provinces.
2. Orissa.
3. South-Western Bengal, or the Chutia Nagpur Province.
4. North-West Provinces, including the Himalayas and Punjab.

* Other authorities on this region are, as quoted by Mr. Foote—Aytoun, Lieutenant, "Trans. Bombay Asiatic Society," Vol. XI., p. 8; Carter, Dr., "Geological Papers on Western India"; Newbold, Capt., No. 4 of "Papers on the Mineral Resources of Southern India."

† "Memoirs Geological Survey of India," Vol. XII., p. 259.

1. CENTRAL PROVINCES.—In the extensive region known as the Central Provinces, and throughout a considerable portion of which metamorphic rocks prevail, gold-bearing rocks and their natural product, auriferous sands, are probably widely distributed; but on this subject but little has been published, and at the present moment I am only able to refer to a paper by Colonel Ouseley,* and to my own notes which apply to the district of Sambalpur, where I made enquiries regarding gold in connexion with those which I instituted in the same locality in reference to diamonds.

The following remarks I have already published,† but I reproduce them here only slightly modified, as they serve to epitomize all that is at present known on the subject.

Gold in all probability occurs pretty generally throughout those portions of the district of Sambalpur, in which metamorphic rocks prevail. So far as I have been able to gather from personal observation, the washers confine themselves to the beds of the Mahanadi and Ebe; but in the rains they are said to leave the larger rivers and wash in the small jungle streams.

In the Ebe, below Tahood, I saw a party of gold-washers encamped on the sand. The places where they were actually washing were within the area occupied by rocks of Talchir (Permio-triassic) age; but whether the gold was proximately derived from them, or had been brought down by the river, as is possible, from the metamorphic rocks a short distance higher up, I am unable to say.

There is, of course, no *primâ facie* improbability in the Talchir rocks containing gold. On the contrary, the boulder-bed, including as it does such a large proportion of materials directly derived from the metamorphic rocks, might naturally be expected to contain gold. In this connexion it may be mentioned that in Australia, a conglomerate bed of Carboniferous age has been found to be auriferous,‡ and the same has been recorded in Nova Scotia.§

As to the methods employed by, and the earnings of, the gold-washers, the remarks about to be made on the gold of Singhbhum apply equally to Sambalpur, and need not be anticipated here.

* "Journal Asiatic Society of Bengal," 1839, Vol. VIII.

† "Records of the Geological Survey of India," Vol. X, p. 190; and "Jungle Life in India," p. 529.

‡ *Vide* "Geol. Mag.," 1877, p. 286. § "Jour. Geol. Soc.," Vol. XXXVI, p. 313.

It may be added, that to the north-west of Sambalpur there are a number of parallel quartzite ridges which, in places, have much the appearance of veins; whether they are bedded or not they are, I think, worthy the attention of the prospector for gold.

Fine quartz reefs also occur in many parts of the district.

ORISSA.—In the province of Orissa gold is reported to occur in the sands of the river Brahmini, in the Pal Lahara, where it is said to be worked to a considerable extent.*

Similarly, it is believed to exist in various rivers in the Native States of Dhenkenal and Keonjhar.†

The above rivers drain areas in which metamorphic rocks are alone believed to prevail; but the already quoted memoir, however, contains the following passage, which may be read in connexion with the passage above as to the occurrence of some of the gold in Sambalpur :—

"Gold is occasionally washed in the Tikaria river, and was also, a few years since, obtained from the sands of the Ouli. The latter case is rather interesting, since the localities are in a sandstone country through which the Ouli mainly flows."

SOUTH-WESTERN BENGAL, or THE CHUTIA NAGPUR PROVINCE.—In giving an account of this area I think it well to quote in full a paper‡ by myself, which records the results of my researches in the districts of Singhbhum and Manbhum.

I do so because I believe this area has not received the attention from prospecting companies which it deserves. In the neighbourhood of Chaibassa, the chief town of Singhbhum, I have been especially struck with the auriferous aspect of the rocks. The earthy slates and shales with magnesian schists, and numerous quartz reefs are precisely the rocks which, judging from all experience, ought to yield gold :—

"The existence of gold in the districts of the south-west frontier of Bengal and in the neighbouring tributary states has long been known. It is found not only in the sands of many rivers and streams, but in some instances it has been mined for in the alluvial and other superficial deposits.

"Colonel Haughton in his interesting memorandum 'On the geological structure and mineral resources of the Singhbhúm Division,'§ has

* "Mem. Geol. Survey of India," Vol. I., p. 88.

† Sterling : "Asiatic Researches of Bengal," 1825, Vol. XV., p. 163.

‡ "Records Geol. Survey of India," Vol. I., 1869.

§ "Jour. Asiatic Soc., Bengal," XXIII., p. 103, 1854.

given an account of the gold washing, and enumerated several localities where gold mining had been, or was, at the time of his visits, carried on. He also quotes from a letter from Mr. Robinson, in which that gentleman states the results of his attempts to establish gold-mining under European superintendence. At Rohobe in Oodipur, where operations were commenced and showed some prospect of being fairly remunerative, the climate proved so 'hot and unhealthy' that it was found that no European could live there, and the works were given up.

"Colonel Haughton says that 'the metal was found some years ago in considerable lumps in the Sona Nuddee of Sonapet in Tamar on the northern extremity of Singhbhúm, and much is still found there.' I have invariably found that the washers have traditions of nuggets having been found at intervals. A nugget from the native State of Jushpur is now in the Geological Museum. Its exact weight I forget, but I believe it to have been about half an ounce.

"The cases of the gold having been found *in situ* are undoubtedly rare. Colonel Haughton speaks of it occurring *in situ* 'a little north of Assuntulea in Khursowa,' but further on he states, 'I have not heard of any instance in which the metal has been found attached to a stone,' so that the former statement must only mean to imply that it is mined for in superficial deposits. Dr. Emil Stœhr states* that traces of gold were found in the copper ores of Singhbhúm. A Mr. Emerson was specially employed by the Singhbhúm Copper Company to investigate the gold resources of the country. He is said to have crushed a quantity of quartz and to have found traces of gold in it; but his operations do not appear to have been sufficiently successful to encourage him to continue. In Chaibássa, I was shown a small nugget of gold in a quartz matrix. It was said to have been obtained in the Kappergudee Ghat, near Kalkapur, in Dholbhum.

"It is not within the scope of the present paper to write a complete résumé of all that is recorded on the subject, but rather to give an account of what has actually come under my own observation in those portions of the districts which have been examined geologically.

"During the season of 1866-67, I fancied that I was able to connect the occurrence of gold in the streams with the existence of certain sub-metamorphic rocks (magnesian and mica schists, slates and quartzites) which were then for the first time met with in Mânbhúm. Being anxious to put this connexion to as rigid a test as circumstances would admit of, and wishing to define, if possible, the exact boundaries within which gold certainly exists and may be reasonably looked for, I, with some difficulty, persuaded two gold washers (man and wife) to accompany me during my examination of the southern portion of the district of Mânbhúm. They remained with me for upwards of three months, washing daily at such places as were pointed out.

"One of the most interesting results is, that the existence of gold in the metamorphic as well as the sub-metamorphic rocks has been satisfactorily proved. This, from various reasons, I was not prepared to expect. Colonel Haughton, who speaks of the granitic gneissose rocks as *igneous*,

* Einige Bemerkungen über den District Singhbhum in Bengalen. Viertel jahrschrift der naturforschenden Gesellschaft. Zurich, 5th year, Part 4, 1860.

states that gold is never found in the streams traversing them. Again, the natives, so far as my experience goes, do not wash in the sands, &c., lying on the metamorphic rocks, although they do not connect the existence of gold in the sands with the vicinity of any particular rock.

"In Mânbhúm, the experience of generations of washers has enabled them to define the boundaries within which washing is remunerative; and this boundary, it is interesting to observe, corresponds on the north exactly with that of the sub-metamorphic rocks.* This coincidence I ascertained in the following manner. On my arrival at Dulmi (which is situated on the faulted boundary of these two groups of rocks) when marching northwards from the lower part of Patkum, the gold-washer asked to be allowed to return to his own country (Dhalbhúm), stating that none of his race ever went north of Dulmi. I induced him however to stop, and while we remained north of the fault the washings were carried on in the granitic gneiss area with comparatively poor, but not exactly barren, results. On the day I crossed the fault south of Sindaree, when returning southwards, the gold-washer said that we should after that find gold more regularly and in greater quantities than we had done since we came north at Dulmi.

"During the whole time, a record was kept of the daily results and of the nature of the rocks in which the washings were made. The following abstract will suffice for comparison of the productiveness of the two formations:—

SUB-METAMORPHICS.

—	Jan.	Feb.	March.	April.	Total.
Number of days on which washings were made, .	31	9	18	8	66.
Unsuccessful days, .	2	3	2	2	9=13·6 per cent.
Gold in grains, . .	17·68	4·65	7·6	2·45	32·38.
Daily average in grains,	·57	·516	·4	·3	Daily average for whole period $=\frac{32 \cdot 38}{66}=\cdot 4$ grains.

METAMORPHICS.

—	Jan.	Feb.	March.	April.	Total.
Number of days on which washings were made, .	–	20	13	–	33.
Unsuccessful days, .	–	13	9	–	22=66 per cent.
Total gold in grains,	–	4·78	·7	–	5·48.
Daily average,	–	·23	·05	-	Daily average for whole period $=\frac{5 \cdot 48}{33}=\cdot 16$.

* A line drawn across the southern part of Mânbhúm from Simlapal on the east through Burrabazar to a little north of Echagurh on the west, roughly indicates the position of the line of boundary between the two formations.

"Comparing the results by the number of successful days first, we may say, that for gold-producing, the sub-metamorphic rocks are to the metamorphics as (100—13·6=)86·4 to (100—66=)34=2·5 : 1; comparing by daily average, the proportions become ·49 : ·16=q. p. 3 : 1. We may therefore conclude that the sub-metamorphics are between two and half and three times as productive of gold as the metamorphics, so that as the gold washers only find a subsistence from washing in the sub-metamorphic area, it is obvious that it would not pay them to work in the metamorphics.

"The greatest amount found on one day was 2·2 grains, but the daily averages given above should not be taken as indicative of the amount of gold to be found by a regular system of working, where the washers would of course be set at favourable spots, and would not have to spend a considerable portion of their time daily, as was the case of the men I employed in making marches before they reached the scene of their labours.*

"Various papers in the Asiatic Society's Journal describe the methods of gold-washing practised in different parts of India. The instruments used, though essentially the same in principle throughout, have local peculiarities of shape, &c., and the manner of manipulation also varies. At Hira Khund, in Sambalpur,† the same instrument and manipulation serve for the separation of both diamonds and gold. In fact the diamonds are found in the middle of the process, the iron sand with specks of gold being the final residue. In Mânbhúm and Singhbhum the instruments used are perhaps more simple than those used in any other place. The dish measures 28″ by 18″, it is hollowed somewhat eccentrically to a maximum depth of about 2½ inches. A scraper formed of a flattened iron hook set in a handle, serves to collect the auriferous sand and gravel which accumulates in the angles of the rocks in the beds of streams. The dish when filled is placed in shallow water, and the operator working with his hands soon separates and throws aside all the coarser gravel and stones, while the agitation of the water serves to carry away all the mud and lighter portions. The dish is then balanced on the palm of the left hand and oscillated to and fro with the right; this serves to throw off the greater portion of the remaining gravel, and the process is completed by a circular motion,

* It is conceivable that the fact of the greater quantity of gold being found in the superficial deposits within the sub-metamorphic area might be attributable to something in the configuration or elevation of the ground conducive to the greater accumulation of gold within that area. I could not, however, discover anything of this kind; the fall to south is gradual throughout both formations. The origin of the gold which is annually found in the rivers at present is, I believe, twofold. A portion being directly derived from the rocks, and the remainder resulting from the re-assortment of detritus which is the remnant of sub-aerial action. In both formations, the evidences of extensive sub-aerial action are numerous and prominent, and it is obvious that nature has been carrying on gold-washing operations in the valleys since denudation first commenced to scoop them out, leaving barriers of intervening ranges of hills formed of the hardest rocks between them.

† "Jour. Asiatic Soc., Bengal," VIII., 1057, 1839.

which is communicated to the water in the hollow of the dish, by which even the smallest particles of foreign matter are separated, and the final result is a residue of black iron-sand in which the specks of gold are readily apparent.

"The gold-washers belong to the lowest and poorest races in the country. Throughout Chutia-Nagpur the tribes who are engaged in this occupation may be classified as follows:—

"First.—The Dohras, or Dokras, of Mânbhúm, who are allied to the Kumars, and profess to be Hindus. Among them both sexes wash for gold.

"Second.—The Ghasis of Singhbhum, among whom the men only wash for gold. The Ghasis are also musicians, and only certain families, or sub-tribes, engage in the former occupation.

"Third.—In the hilly country, west of Singhbhum, among certain of the Kol or Munda tribes, the women wash for gold during the rains; but the men regard the occupation as unworthy work for their sex.

"The methods employed by these different tribes appear to be identical in all essentials, and similar to the process just described. Each occupies a distinct tract, and poaching on each other's favourite streams is not indulged in to any great extent.

"Their numbers were greatly reduced by the famine of 1866; without exception they are all in the power of the Mahajuns, for whom they work at a low rate, and are never able to free themselves of the claims which the Mahajuns make on account of advances.

"The daily earnings of the gold-washers are small, but might, no doubt, be increased, if it were not that they are always satisfied when enough gold has been found for procuring the day's subsistence.

"Colonel Haughton says:—'The Ghasis can always reckon on earning from three to four pice per day, and I am assured that a vigorous man often gets as much as twelve annas, which, as the ordinary rate of field labour is about one pice, must be considered a very large sum.'* Mr. Robinson found in a trial which he made at Rohobe, in Oodipur, that men to whom he paid one anna could produce for him from three to four annas worth of gold. Colonel Dalton states that the washers themselves regard it as a very poor trade, simply yielding they say, *pêt bur* (bellyful). Dr. Stœhr, in his paper on Singhbhúm, states that he found the average daily earning to be about 25 centimes (rather more than an anna and a half). The men I met with stated that they could earn about an anna a day, and occasionally three or four annas.

"The simplest idea of the process of hydraulic mining, which seems so nearly to approach to perfection in California, is not altogether unknown to the natives. Mr. Robinson says†:—'Another plan, and a very remarkable one, in which the people collect the gold, is by drawing up small watercourses before the rains, so as to make places for a deposit of soil carried down by the water; this soil is cleared out several times and in it is found a large deposit of gold.'

"In the shallow diggings the hydraulic system would not, of course,

* "Jour. Asiatic Soc., Bengal," 1854, p. 109. † *Ibid.*, p. 108.

be applicable; but even in them an increased yield would undoubtedly result from supplanting the native's dish by the Californian pan, rocker long-tom, and sluice."

NORTH-WEST PROVINCES, INCLUDING THE HIMALAYAS AND PUNJAB.

In the North-West Himalayas the occurrence of gold has been alluded to by many travellers, but the following notices from the official publications of the Geological Survey of India, contain the most important facts in connexion therewith.

"There are gold-washings carried on yearly in the beds of the Himalayan rivers, and most extensively, even in streams which only drain the sub-Himalayan rocks. The fact is rather interesting; since in these streams the gold must have a doubly derivative origin."*

"*Sona River, Gurhwal District.*—This stream rises in the lower range of hills, and joins the Ramgunga river in Paltí Dhún. Its sands yield gold, and the bed of the Ramgunga below the junction is auriferous. The washing is not very profitable, scarcely averaging four annas a day to each workman."

Again:—

"The sands of the Ganges, running through Taluka Chandi, contain gold, but the profit arising from the washing is not greater than in the Sona river."†

Punjab.

"Gold is washed for in the Indus, at Kalabagh, sometimes also in the Bunhar river bed at the other end of the range (Salt Range), and in several small streams along its northern flanks, *the present source of the precious metal* being the Tertiary sandstone formation, and apparently among the lower beds of the Lower Sivalik group. The process is not continuous, being only carried on after heavy falls of rain in the smaller streams, and in the Indus when floods permit. The amount realized can hardly be closely ascertained, for as the industry is taxed it is the interest of the operators to conceal their gains. According to the best information obtainable these fluctuate from three to four annas worth a day per man, this being generally thought rather above the measure of success."‡

The gold washing in the Salt Range is described in some detail by Dr. Fleming, in his Report.§

Dr. Jameson also alludes to the gold which is found there.||

* Medlicott: "Mem. Geol. Survey of India," Vol. III., p. 179.

† Lawder: "Records of the Geological Survey of India," Vol. II., 88, 90.

‡ Wynne: "Mem. Geol. Survey of India," Vol. XIV., 303.

§ "Jour. Asiatic Society, Bengal," 1853, p. 230.

|| "Jour. Asiatic Society, Bengal," Vol. XI., p. 1.

ULTRA PENINSULAR AREAS.

The principal gold producing countries beyond, but adjoining the limits of peninsular India, are on the east:—

1. *Assam.*
2. *Burmah.*

And on the west and north:—

3. *Afghanistan.*
4. *Thibet.*

1. ASSAM.—In Assam Capt. Dalton and Col. Hannay carried on researches in reference to the occurrence of gold, which were made public through the medium of the Journal of the Asiatic Society of Bengal.* Subsequently the same gentlemen were requested by Government, in the year 1855, to undertake a further examination of the auriferous deposits of Upper Assam, and were supplied with ample funds for carrying out their investigations.

From an abstract of their reports by Dr. T. Oldham, late Superintendent of the Geological Survey of India, I quote the following:—†

Gold was obtained in the Brahmaputra at Parghat, above Sudya, and in several tributaries, Noa-Dehing, Dihong, and Hookong. "The spots selected by the natives are those salient angles or reaches of the river, where the alluvial deposits, cut away by the stream from the opposite bank, are partially re-deposited, after having undergone the sifting action of the current."

The gold "is derived from the crystalline rocks in the first instance, but only becomes sufficiently concentrated to render it worth working in the alluvium, after this alluvium has undergone repeated washings in the river current, by being successively cut away, washed and re-deposited as the river changes its course."

The Dihong river from the hills to the north "yielded gold in considerable quantity, from its junction with the Brahmaputra to about half way between that stream and the hills." $5\frac{5}{7}$ tons of gravel yielded 90 grains of gold=$16\frac{1}{8}$ grs. per ton. "This stream is considered by the natives to be the richest in Assam."

"The apparatus used in these investigations were a Californian Cradle (long-tom) worked by four men, and which was found to give the largest daily yield per man; and a Singpho washing dish worked by one washer and one assistant."

No. 1 Gold from Brahmaputra	yielded	88·281	per cent.	pure gold.
No. 2 Noa Dehing	„	93·880	„	„
Dihong	„	90·234	„	„
Hookong	„	86·588	„	„

* Vol. VII., p. 625, and Vol XII., p. 511.

† "Mem. Geol. Survey of India," Vol. I., p. 90.

BURMAH.—The following facts are taken from a paper by Dr. Oldham, entitled "Notes on Specimens of Gold and Gold dust procured near Shue Gween, in the province of Martaban, Burmah."*

"Gold-bearing sands and nuggets were forwarded from Shue Gween to Dr. Oldham who obtained from the former, amounting to about the fifth of a cubic foot in bulk, ·75 of a grain of gold by washing and 0·20 by the aid of mercury=·95. The sand consisted of particles of metamorphic rocks. The gold on assay proved to consist of 92 per cent. of pure gold and 8 per cent. of silver."

The natives washed in the Shue Gween river from time immemorial, and under the Burmese Government there was a Farmer General who paid a certain sum to the royal treasury and sub-let the privilege of washing to numbers of persons."

Mr. Theobald, of the Geological Survey, writes as follows regarding gold in the Irrawadi :—†

"Gold occurs in the bed of the Irrawadi, but in such fine dust and so sparingly that few engage in the task of washing for it. I am told that it is occasionally washed before Prome, but the only spot where I have witnessed the process is at Shuaygyeing (Gold scratching), not to be confounded with Shuay Gyeen on the Sittoung, just above Monyo, where a little gold is obtained. The gold is found in a coarse gravel bank, left dry by the river when it subsides after the rains."

"This coarse gravel is dug out and laid on a sort of hurdle, which permits the fine sand to pass through, the coarse pebbles and boulders being rejected. This sand is washed on an inclined board; the lighter portion being gradually swept down the incline by a stream of water directed over it, whilst the heavy auriferous sand remains, and is from time to time collected. This sand is lastly washed in the common wooden hand dish, of circular form, and the gold it contains *collected by amalgamation*. The profits of this pursuit are small, and the labour great; the men not getting more than two or three annas a day profit, which must be regarded as a miserable remuneration, where the ordinary hire for a Cooly is eight annas, or twice that at the rice ports during the shipping season."

In another paper on the "Metalliferous resources of British Burmah," Mr. Theobald says :—‡

"Though of slight economic importance, gold occurs in most parts of Burmah, but is very little worked within British territory, which I attribute to the higher and more certain remuneration there obtainable for agricultural or other labour; and gold working is therefore pursued mainly in bad seasons, or as an exceptional means of industry taken up merely now and again."

* "Mem. Geological Survey of India," Vol. I., p. 94.

† Ibidem, Vol. X., p. 343.

‡ "Records Geol. Survey of India," Vol. VI., p. 95.

Tavernier* in his enumeration of the places where gold is produced in Asia mentions the kingdom of Tipra (? the modern Tipperah). He says, "it is coarse, almost as bad as that of China."

Other references to the gold of Burmah are to be found in various works descriptive of that country.

AFGHANISTAN.—There is a gold mine a little to the north of Kandahar city. It appears to be in quartz veins, which are superficially excavated, gunpowder being employed. The gold is sometimes chiselled out in pure granules, the stone is not taken out unless it contains visible gold. It is taken into the city for treatment. The mine belonged to the Government; had been worked anyhow for some twelve years, and in 1872 was leased to a contractor for Rs. 5,000 a year. As much more was spent on working the mine, and the yearly out-turn was said to exceed Rs. 10,000.

THIBET.—I include Thibet in this account as there is every reason to believe that for very many centuries a regular supply of gold has entered India from thence, and continues to do so to the present day. In a paper by Mr. A. Lawder on the "Mineral Statistics of the Kumaon District,"† we find the following passage :—

> " Gold is found in many of the rivers of Thibet, at Silungsakka, &c.; it is sold at the same fairs as the salt and borax, either in nuggets or grains. About 10 to 12,000 rupee's worth is brought down annually, some of which is disposed of in the hill districts (Kumaon and Gurhwal), probably about one-third, and the remainder most likely finds its way to Delhi, Agra, &c. It is sometimes found to contain copper."

Tavernier* mentions the occurrence of gold in Thibet, though he was not aware apparently of its being worked in his time in Southern India. He says :—

> "Toward the Thibet, which is the ancient Caucasus, in the territories of a Raja beyond the Kingdom of Cachemir, there are three mountains close one by another, one of which produces gold, the other *granats* (garnets), and the third lapis lazuli."

Of the very highest interest are the accounts of the Thibetan gold mines, which are given by the Pundits attached to the Indian Survey for the purpose of exploring countries north of the Himalayas. Unwittingly these admirable native servants of the Government of India have furnished facts which have enabled

* Travels. † "Records of the Geological Survey of India," Vol. II., p. 90.

Sir Henry Rawlinson, and independently Professor Frederik Schiern, Professor of History at the University of Copenhagen, to clear up a mystery which has been a puzzle to the historians and philosophers of many countries for upwards of 2,000 years. A translation of Professor Schiern's paper,* by Anna M. H. Childers, will be found in the "Indian Antiquary."† It is a most remarkable example of learned research, and one very difficult to give in abstract. It is entitled "The Tradition of the Gold-digging Ants." But perhaps before giving the conclusions which Sir Henry Rawlinson and Professor Schiern have arrived at, will be best in this place to briefly describe the Pundits' observations:—

"During the expedition of 1867 the Pundit who had been at Lassa fell in at Thok Jalung, an important gold field in the province of Nari Khossam, with a large encampment of Thibetan miners, and took the opportunity to gain information relative to the working of the mines. In the third expediton, in 1868, another Pundit passed on as far as Rudok, at the north west extremity of Chinese Thibet, on the frontier of Ladak, and on his way back from Rudok visited the gold fields of Thok Nianmo, Thok Sarlung,‡ and Thok Jarlung. The map which accompanies Major Montgomery's narrative of the journeys of the Pundits gives in addition the gold fields of Thok Munnak, Thok Ragyok, Thok Ragung, and Thok Dalung." . . . "The miners' camp at Thok Jarlung, according to the measurements of the Pundits, is 16,300 feet above the sea level."

The cold is intense, and the miners in winter are thickly clad with furs.

"The miners do not merely remain under ground when at work, but their small black tents, which are made of a felt-like material manufactured from the hair of the Yak, are set in a series of pits, with steps leading down to them . . . seven or eight feet below the surface of the ground." . . . "Spite of the cold the diggers prefer working in winter; and the number of their tents, which in summer amounts to 300, rises to nearly 600 in winter. They prefer the winter as the frozen soil then stands well, and is not likely to trouble them much by falling in."

* Verhand. Kgl. Danischen Gesellsch. der Wissensch. for 1870. Printed separately in Danish, German, and French.

† Vol. IV., p. 225.

‡ Thok Sarlung had at one time been the chief gold field of the district, "but had in a great measure been abandoned on the discovery of the Thok Jarlung gold field. The Pundit passed a great excavation some 30 to 40 feet deep, 200 feet in width, and two miles in length from which the gold had been extracted."—"Jour. As. Soc. Bengal." Vol. XXXIX., Pt. 2, p. 53, 1870.

They are occasionally attacked by bands of robbers who carry off their gold.

Sir Henry Rawlinson's remarks on these reports of the Pundits' researches and travels are as follows:—*

"Now, then, for the first time, we have an explanation of the circumstances under which so large a quantity of gold is, as is well known to be the case, exported to the west from Khoten, and finds its way into India from Thibet; and it is probable that the search for gold in this region has been going on from a very remote antiquity, since no one can read the ex-Pundit's account of the Thibetan miners 'living in tents some seven or eight feet below the surface of the ground, and collecting the excavated earth in heaps previous to washing the gold out of the soil,' without being reminded of the description which Herodotus gives of the 'ants in the land of the Indians bordering on Kaspatyrus (or Kasmir) which made their dwellings underground, aud threw up sand heaps as they burrowed, the sand which they threw up being full of gold.'"

Professor Schiern points out that the tradition was mentioned in writings of the middle ages, and those by Arabian authors. It survived among the Turks. Strabo and Albertus Magnus treated the whole story as a fiction. Xivrey supposed that the animals had become extinct owing to the *auri sacra fames.* Major Rennell supposed that the dwellers in mounds were *termites* or white ants. Humboldt's observations in Mexico on the habit of certain ants to carry about shining particles of hyalith was quoted by those who believed that the animals were really ants. Other authorities suggested that they were marmots, jackals, foxes, or hyænas. Pliny having stated that horns of the Indian ant were preserved in the temple of Hercules at Erythice—Samuel Wahl, who maintained the hyæna theory, proved equal to the difficulty by suggesting that the horns might have been a *lusus naturæ.*

Professor Schiern most ingeniously argues that the horns had been taken from the skins of animals which formed the garments of the miners.

I may, perhaps, add to the evidence given on this subject by Professor Schiern, that I have seen bullock horns worn as a head decoration by a tribe (the Khonds) in India, and, indeed, I possess a photograph of an individual so adorned.

Professor Schiern further points out that ancient writers say

* *Pall Mall Gazette*, March 16, 1869, quoted in "Indian Antiquary," Vol. IV., p. 225.

that the ants worked chiefly in winter, and connects this with the statement of the Pundit above quoted.

In conclusion he writes:—

"For us the story partakes no longer of the marvellous. The gold-digging ants were originally neither real ants, as the ancients supposed, nor, as the many eminent men of learning have supposed, larger animals mistaken for ants on account of their subterranean habits, but men of flesh and blood, and these men Thibetan miners, whose mode of life and dress were in the remotest antiquity, exactly what they are at the present day."

I append an extract from Sir Henry Rawlinson's translation of the passage in Herodotus, as it may be of interest to some readers:—

"Besides these there are Indians of another tribe, who border on the city of Kaspatyrus and the country of Paktyika: these people dwell northward of all the rest of the Indians, and follow nearly the same mode of life as the Bactrians. They are more warlike than any of the other tribes, and from them the men are sent forth who go to procure the gold, for it is in this part of India that the sandy desert lies. Here in this desert there live, amid the sand, great ants, in size somewhat less than dogs, but bigger than foxes. The Persian king has a number of them, which have been caught by the hunters in the land whereof we are speaking. These ants make their dwellings underground, and, like the Greek ants, which they very much resemble in shape, throw up sand heaps as they burrow. Now, the sand which they throw up is full of gold. The Indians when they go into the desert to collect this sand take three camels and harness them together, a female in the middle, and a male on either side in a leading-rein. The rider sits on the female, and they are particular to choose for this purpose one that has just dropped her young: for their female camels can run as fast as horses, while they bear burdens very much better. . . . When, then, the Indians reach the place where the gold is, they fill their bags with the sand and ride away at their best speed: The ants, however, scenting them, as the Persians say, rush forth in pursuit. Now, these animals are so swift, they declare, that there is nothing in the world like them: if it was not, therefore, that the Indians get a start while the ants are mustering, not a single gold-gatherer could escape. During the flight the male camels, which are not so fleet as the females, grow tired, and begin to drag, first one and then the other, but the females recollect the young which they have left behind, and never give way or flag. Such, according to the Persians, is the manner in which the Indians get the greater part of their gold: some is dug out of the earth, but of this the supply is more scanty."

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APPENDIX.

LIST OF FELLOWS, CORRECTED TO DECEMBER 31, 1878.

Fellows are requested to correct errors in this List, by Letter to the REV. DR. HAUGHTON, Treasurer, Trinity College, Dublin.

OFFICERS OF THE SOCIETY FOR THE YEAR 1878–9.

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HONORARY FELLOWS.

Elected.

1844. 1. Boué, M. Ami, For. Mem. L.G.S., M.D., *Académie Imp. Sc., Vienna.*

1865. 2. Burton, Captain R. F., *Royal Geographical Society*, 1, *Savile Row, London.*

1861. 3. Daubrée, M., Membre de l'Institut, 91, *Rue de Gréville, St. Germains, Paris.*

1861. 4. Delesse, M., Ingénieur des Mines, *Paris.*

1865. 5. Des Cloiseaux, M., Prof. of Mineralogy, *Jardin des Plantes, Paris.*

1861. 6. De Serres, M. Marcel, *Montpellier.*

1861. 7. Deville, M. H. Ste.-Claire, 8, *Rue des Vieux Colombieres, Paris.*

1861. 8. De Koninck, M. L., For. Mem. L. G. S., *Liège.*

1861. 9. Geinitz, M. H. B., For. Mem. L. G. S., *Dresden.*

1863. 10. Hunt, Dr. T. Sterry, F. R. S., *Institute of Technology, Boston, U. S.*

1873. 11. Jones, Professor T. Rupert, F.R.S., *Fosse Bank, West, Camberley, Surrey.*

1861. 12. M'Clintock, Rear-Admiral Sir Leopold, R. N., C. B., F. R. S., *Dockyard, Portsmouth.*

HONORARY CORRESPONDING FELLOWS.

Elected.
1859. 1. Gordon, John, C. E., *India.*
1859. 2. Hargrave, Henry J. B., C. E., *India.*
1859. 3. Hime, John, C. E., *Ceylon.*
1858. 4. Kingsmill, Thomas W., Shanghai, *China.*
1855. 5. Medlicott, Joseph, *India.*

FELLOWS WHO HAVE PAID LIFE COMPOSITION.

1853. 1. Allen, Richard Purdy, Chelmsford House, Angell Road, Brixton, London, S. W.
1857. 2. Carson, Rev. Joseph, D. D., S. F. T. C. D., *Trinity College.*
1857. 3. Dowse, Rt. Hon. Baron, 38, *Mountjoy-square, South.*
1872. 4. Durham, J. S. W., *Rosenthal, Torquay, Devon.*
1861. 5. Fottrell, Edward, *Drayton, Cambridge-road, Rathmines.*
1862. 6. Frazer, W., F. R. C. S. I., 20, *Harcourt-street.*
1857. 7. Greene, John Ball, 6, *Ely-place.*
1848. 8. Haughton, Rev. Professor, M. D., F. R. S., 40, *Trinity College*, or 31, *Upper Baggot-street.*
1862. 9. Henry, F. H., *Lodge Park, Straffan, county Kildare.*
1850. 10. Hone, Nathaniel, M. R. I. A., *St. Doulough's, county Dublin.*
1867. 11. Kane, Sir Robert, F. R. S., *Fortlands, Killiney, Co. Dublin.*
1866. 12. Lalor, J. J., 6, *Upper Fitzwilliam-street.*
1856. 13. Lentaigne, John, M. D., 6, *Great Denmark-street.*
1851. 14. Malahide, Lord Talbot de, F. R. S., *Malahide Castle, Malahide.*
1876. 15. Mayne, Thomas, 2, *Glenart Avenue, Blackrock, Co. Dublin.*
1846. 16. Murray, B. B., *County Survey Office, Downshire-road, Newry.*
1872. 17. O'Brien, William, *Ailesbury House, Merrion, county Dublin.*
1852. 18. O'Kelly, Joseph, 14, *Hume-street.*
1857. 19. Porter, William, C. E.
1849. 20. Sidney, F. J., LL.D., 19, *Herbert-street.*
1864. 21. Symes, Richard Glascott, 14, *Hume-street.*
1851. 22. Whitty, Rev. John Irvine, LL.D, 94, *Lower Baggot-street.*

FELLOWS WHO HAVE PAID HALF LIFE COMPOSITION.*

1868. 1. Backhouse, Henry, 2, *Ontario-terrace.*
1875. 2. Boot, John Thomas, *Hucknall, Mansfield.*
1866. 3. Bradley, Samuel, *Little Castle, Castlecomer.*
1873. 4. Broughton, Frederick, LL.D., *Hamilton, Ontario.*
1862. 5. Carter, T. S., *Watlington Park, Watlington, Oxfordshire.*
1867. 6. Clark, George R., C. E., *Northern Bengal State Railway, Parbatipur, Dinagepore, Bengal.*
1854. 7. Clemes, John.

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* EXTRACT FROM BY-LAWS.

"Any person not residing for more than sixty-three days in each year within twenty miles of Dublin shall be a Fellow for Life, or until he comes to reside within the above distance, on paying to the Treasurers the sum of £5 5*s*.

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Elected.
1870. 8. Cooke, Samuel, C. E., *Civil Engineering College, Poona, Bombay.*
1873. 9. Cooper, J. A., M.D., *Civil Surgeon of Hissar Hissar, Bengal.*
1873. 10. Cox, Charles C., *Ashby House School, Walsall.*
1857. 11. Crawfurd, Robert, C. E.
1861. 12. Crosbie, William, *Ardfert Abbey, Ardfert, Tralee.*
1868. 13. Cruise, Richard J., *Geological Survey*, 14, *Hume-street, Dublin.*
1873. 14. Cunningham, Professor R. O., M. D. Edin., *Queen's College, Belfast.*
1874. 15. Devine, Thomas, *Deputy Surveyor-General for Ontario, Toronto, Canada.*
1873. 16. Dobbs, Josiah, *Coolbaun, Castlecomer, Kilkenny.*
1866. 17. Duffin, W. E. L'Estrange, *County Survey Office, Limerick.*
1861. 18. Dunally, Lord, *Kilboy, Nenagh.*
1876. 19. Dunscombe, Clement, M. A., C. E., Public Offices, Derby.
1872. 20. Egan, F. W., 14, *Hume-street.*
1866. 21. Ellis, R. H.
1871. 22. Emerson, Rev. J. M., 99, *Bushfield-avenue, Dublin.*
1869. 23. Enniskillen, Earl of, F. R. S., M. R. I. A., *Florence Court, Enniskillen.*
1872. 24. Gore, J. E., *care of C. S. Rundle, Esq., C. E., Umballa Post-office, Punjab, India.*
1871. 25. Hardman, E. T., 14, *Hume-street.*
1861. 26. Harte, W., C. E., *Donegal County Surveyor, Office, Londonderry.*
1856. 27. Haughton, Major John, R. A., *Bengal.*
1850. 28. Head, Henry, M. D., 7, *Fitzwilliam-square.*
1858. 29. Hill, J., C. E., *Ennis, county Clare.*
1862. 30. Hudson, R., F. R. S., F. L. S., *Clapham Common, London.*
1839. 31. James, Sir H., Major-General R. E., F. R. S., *Ordnance Survey Office, Southampton.*
1857. 32. Keane, Marcus, *Beech Park, Ennis, county Clare.*
1871. 33. Kelly, G. N. H., *Fair-street, Drogheda.*
1862. 34. Kinahan, G., J. P., *Roebuck Hill, Dundrum, county Dublin.*
1853. 35. Kinahan, George H., 14, *Hume-street.*
1862. 36. Kincaid, Joseph, Jun., C. E.
1838. 37. Larcom, Major-General Sir Thomas, R. E., LL.D., F.R.S., *Heathfield, Fareham, Hants.*
1874. 38. Laurence, Rev. Chas., *Lisreaghan, Laurencetown, county Galway.*
1858. 39. Leach, Lieut.-Colonel, R. E., 3, *St. James's-square, London, S. W.*
1868. 40. Leonard, Hugh, 14, *Hume-street.*
1875. 41. Lilley, Rev. Charles, M. A., *Head Master of Ware Grammar School, Ware, Herts.*
1840. 42. Lindsay, Henry L., C. E., *Melbourne, care of J. Bower, Esq., C. E.*, 28, *South Frederick-street.*
1867. 43. Meadows, J. M'Carthy.
1874. 44. Meadows, Joseph, Jun., *Thornville, county Wexford.*
1840. 45. Montgomery, James E., M. R. I. A.
1856. 46. Moloney, C. P., *Capt. 25th Regiment, Madras N. I., per Messrs. Grindlay and Co.*, 3, *Cornhill, London.*
1856. 47. Medlicott, Henry B., F. G. S., *Geological Survey of India, per Smith and Elder, Cornhill, London, E. C.*
1857. 48. M'Ivor, Rev. James, *Rectory, Moyle, Newtownstewart, county Tyrone.*
1865. 49. Morton, G. H., 122, *London-road, Liverpool.*
1845. 50. Neville, John, C. E., M. R. I. A., *Dundalk.*
1870. 51. Nicolls, Thomas, C. E., *Resident Engineer, Yorkshire and Lancashire Railway, Manchester.*
1868. 52. Nolan, Joseph, 14, *Hume-street.*
1832. 53. Renny, Henry L., R. E., *Canada.*
1870. 54. Rigby, Jason, C. E., 49, *Park-avenue, Sandymount.*
1873. 55. Rowney, Professor T., Ph. D., *Queen's College, Galway.*
1875. 56. Scholfield, Amos, M. A., *Clyde Cottage, Redland Vale, Bristol.*

Elected.
1854. 57. Scott, R. H., M. A., F. R. S., *Meteorological Office*, 116, *Victoria-street, London.*
1872. 58. Sharpe, R. W.
1868. 59. Siree, P. H., C. E.
1854. 60. Smyth, W. W., F. R. S., *Jermyn-street, London.*
1865. 61. Steele, Rev. W., *Portora Royal School, Enniskillen.*
1871. 62. Sturman, Dr. E. A., *Queen's College, Penge, London, S. E.*
1857. 63. Tate, Alexander, C. E., *Queen's Elms, Belfast.*
1870. 64. Taylor, J. E., F. G. S., *Bracondale, Norwich.*
1832. 65. Tighe, Right Hon. William, *Woodstock, Innistiogue.*
1866. 66. Townsend, H. W., *Clonakilty.*
1871. 67. Traill, William A., *Geol. Survey, Ballymena, Co. Antrim.*
1873. 68. Trench, J. Townsend, *Kenmare.*
1866. 69. Wall, H. P., *Portarlington.*
1864. 70. Waller, G. A., 2, *Longford-terrace, Monkstown, county Dublin.*
1853. 71. Webster, William B.
1871. 72. Weldon, Major Frank, per Messrs. Grindlay & Co., 3, *Cornhill, London.*
1872. 73. White, H. V., C. E., *County Surveyor, Longford.*
1872. 74. White, John N., *Waterford.*
1876. 75. Whiston, William, M. A., *Collegiate Academy, Chapel-Chorlton, near Newcastle, Staffordshire.*
1861. 76. Whitney, C. J., *Brisbane, Queensland.*
1846. 77. Wilson, Walter.
1864. 78. Wright, Joseph, *Cliftonville, Antrim-road, Belfast.*
1854. 79. Wyley, Andrew.
1857. 80. Wynne, Arthur B., F. G. S., *Geological Survey of India, Calcutta.*

ANNUAL FELLOWS.

1875. 1. Adams, Professor A. Leith, M. B., F. R. S., *Royal College of Science, Stephen's-green.*
1878. 2. Ball, Valentine, 43, *Wellington-place, Dublin.*
1861. 3. Barrington, E. E., M. B., *Enniskerry.*
1862. 4. Barton, Henry M., 4, *Foster-place.*
1857. 5. Carte, Alexander, M. D., F. L. S., *Royal Dublin Society.*
1862. 6. Close, Rev. Maxwell, 40, *Lower Baggot-street, Dublin.*
1874. 7. Crawley, J. Chetwode, B.A., 3, *Ely-place, and* 66, *Mountjoy-square, W.*
1849. 8. Downing, Samuel, LL.D., C. E., *Trinity College*, or 4, *The Hill, Monkstown.*
1876. 9. Fitt, Decimus, C.E., *care of Messrs. Courtney and Stephens*, 2, *Blackhall-place.*
1865. 10. Fleming, John M., C.E., Surveyor, War Department, *Hong Kong.*
1866. 11. Foot, A. W., M. D., 49, *Lower Leeson-street.*
1858. 12. Gages, Alphonse, M. R. I. A, 51, *Stephen's-green.*
1857. 13. Hampton, Thomas, C. E., 6, *Ely-place.*
1861. 14. Hudson, A., M. D., 2, *Merrion-square, North.*
1870. 15. Hull, Edward, M. A., F. R. S., 14, *Hume-street.*
1865. 16. Hutton, T. M., 118, *Summer-hill.*
1842. 17. Jennings, F. M., M. R. I. A., *Brown-street, Cork.*
1866. 18. Knapp, W. H., C. E., *Wellington Lodge, Kingstown.*
1831. 19. Lloyd, Rev. Humphrey, D.D., F. R. S., Provost T. C. D., *Provost's House.*
1863. 20. Macalister, A., M. B., 5, *Trinity College.*
1878. 21. M'Carthy, W. S., M.D., 66, *Mountjoy-square, West.*
1878. 22. M'Henry, Alexander, *Geological Survey Office*, 14, *Hume-street, Dublin.*
1863. 23. M'Donnell, Alexander, C. E., *St. John's, Inchicore.*
1851. 24. M'Donnell, John, M. D., 32, *Upper Fitzwilliam-street.*

Elected.
1876. 25. M'Nab, Professor W. R., M. D., *Royal College of Science.*
1859. 26. Moore, Joseph Scott, J. P., 12, *Hume-street, and Beulah, Dalkey.*
1874. 27. Porte, George, 43, *Great Brunswick-street.*
1864. 28. Reynolds, J. Emerson, M. D., 62, *Morehampton-road.*
1857. 29. Reeves, Robert S., 5, *Fitzwilliam-place.*
1861. 30. Roberts, W. G., 7, *Cornwallis-terrace, Clifton, Bristol*
1877. 31. Rochford, John, *Education Office, Marlborough-street, Dubln.*
1875. 32. Ross, George M., *Ballinagowan House, Rathmines.*
1862. 33. Rowan, D. J., C. E., *Woodburn, Blackrock, Co.Dublin.*
1861. 34. Stoney, Bindon, C. E., 42, *Wellington-road.*
1875. 35. Taylor, F. C., *Summerleaze Collegiate School, East Harptree, near Bristol.*
1864. 36. Tichborne, C. R. C., Ph. D., F. C. S., *Apothecaries' Hall, Mary-street,* or 23, *Middle Gardiner-street.*
1863. 37. Westropp, W. H. S., M. D., *Lisdoonvarna, county Clare.*
1863. 38. Williams, Richard Palmer, 38, *Dame-street.*
1877. 39. Young, Peter, *Education Office, Marlborough-street, Dublin.*

SUMMARY.

Honorary Fellows, ...	12
Corresponding Fellows, ...	5
Life Fellows, ...	22
Half Life Fellows, ...	80
Annual Fellows, ...	39
Total, . .	158

SOCIETIES AND INSTITUTIONS TO WHICH THE JOURNAL OF THE ROYAL GEOLOGICAL SOCIETY OF IRELAND IS SENT.

ABERDEEN ..	University Library.
ALBANY ..	State Library, New York.
AMSTERDAM ..	Royal Academy of Sciences.
ANTWERP ..	Palæontological Society of Belgium.
BELFAST ..	Queen's College Library.
	Naturalists' Field Club.
BERLIN ..	Royal Prussian Academy of Sciences.
	German Geographical Society.
	German Geological Society, per Besserche Buchhandlung, *Behrenstrasse*, 7, *Berlin.*
BOLOGNA ..	Academy of Sciences of the Institute.
BORDEAUX ..	Society of Physical and Natural Sciences.
BOSTON ..	American Academy of Arts and Sciences.
	Natural History Society.
BRISTOL ..	Institution for the Advancement of Science, Literature, and the Arts.
BRÜNN ..	Natural History Association.
BRUSSELS ..	Royal Academy of Sciences, Letters, and Fine Arts of Belgium.
CAEN	Linnæan Society of Normandy.
CALCUTTA ..	Asiatic Society.
	Public Library.
	Geological Survey of India.
CAMBRIDGE ..	Philosophical Society.
	Trinity College Library.
CANTERBURY, NEW ZEALAND ..	Geological Survey.
COPENHAGEN	Royal Danish Academy of Science and Letters.
CORK	Queen's College Library.
	Royal Institution.
DIJON	Academy of Sciences, Arts, and Literature.
DRESDEN ..	"Isis" Natural History Society.
DUBLIN ..	Royal College of Surgeons' Library.
	Royal Irish Academy.
	University Library.
	Royal Dublin Society.
	Ordnance Survey Library.
	Geological Survey of Ireland.
	Institution of Civil Engineers.
EDINBURGH ..	Royal Society of Edinburgh.
	Edinburgh Geological Society.
	Royal Scottish Society of Arts.
	University Library.
	Society of Antiquaries.
	Advocates' Library.
FALMOUTH ..	Royal Cornwall Polytechnic Society.
FLORENCE ..	Italian Society of Sciences.
GALWAY ..	Queen's College Library.
GENEVA ..	Society of Physics and Natural History.
GLASGOW ..	University.
	Glasgow Geological Society.
GÖTTINGEN ..	University.
HALLE ..	Natural History Association for Saxony and Thüringia, per Antons Buchhandlung, *Halle.*

HANAU	..	Upper-Hessian Society of Natural and Medical Science.
HANOVER	..	Royal Library.
HARLEM	..	Dutch Society of Exact and Natural Sciences.
		Teyler Institution.
KILKENNY	..	Archæological Association of Ireland.
KÖNIGSBERG		Royal Physical and Economical Society.
LAUSANNE	..	Vaudian Society of Natural Sciences.
LEEDS	..	Geological and Polytechnic Society of the West Riding of Yorkshire.
		Philosophical and Literary Society.
LEIPSIC	..	Royal Saxon Society of Sciences.
		University.
LIVERPOOL	..	Literary and Philosophical Society.
		Historic Society of Lancashire and Cheshire.
		Liverpool Geological Society, The Royal Institution, *Colquitt-street*.
LONDON	..	Geological Survey, *Jermyn-street*.
		British Museum.
		Society of Arts, *John-street*, *Adelphi*.
		Royal Institution, *Albemarle-street*.
		Royal Society, *Burlington House*.
		Geological Society, *Burlington House*.
		Linnæan Society, *Burlington House*.
		Royal Geographical Society, 15, *Whitehall-place*.
		Civil Engineers, Institution of, 25, *Great George-street*, *Westminster*.
		Royal Asiatic Society, 22, *Albemarle-street*.
		Royal College of Surgeons, *Lincoln's Inn*.
		Zoological Society, 11, *Hanover-square*.
		Geological Magazine, Editor of.
		Athenæum, 14, *Wellington-street*, *Strand*, *London*, *W. C.*
		Anthropological Society, 4, *St. Martin's-place*, *London*, *W. C.*
LYONS	.. ..	Society of Agriculture, Natural History, and Useful Arts.
		Linnæan Society.
		Academy of Sciences, Literature, and Arts, per Treuttel & Wurtz, 19, *Rue de Lille*, *Paris*.
MADRID	..	Royal Academy of Sciences.
		Geographical Society.
MANCHESTER		Literary and Philosophical Society of.
		Manchester Geological Society.
MELBOURNE		Philosophical Institute of Victoria.
		Public Library, per Bain and Co., 1, *Haymarket*, *London*.
		Royal Society of Victoria.
MILAN	.. ..	Royal Lombard Institution of Sciences.
MISSOURI	..	State Survey and University, *Geological Rooms*, *Columbia*, *U. S. A.*
MONTREAL	..	Natural History Society.
MUNICH	..	Royal Bavarian Academy of Sciences.
NANCY	..	Society of Sciences.
NEUFCHATEL		Society of Natural Sciences.
NEW HAVEN, U. S. A.	..	Connecticut Academy of Arts and Sciences.
		Editors of Silliman's Journal of Science and Art.
NEW YORK	..	State Museum of Natural History.
OXFORD	..	Bodleian Library.
		Ashmolean Society.
PALERMO	..	Academy of Sciences and Letters.
PARIS	.. ..	Polytechnic School.
		Geological Society.
		School of Mines.
		Institute of France.
		National Library.
PARIS	.. ..	Jardin des Plantes, Library.

PHILADELPHIA	American Philosophical Society.
	Academy of Natural Sciences, per Trübner and Co.
PISA	Tuscan Society of Natural Sciences.
PLYMOUTH ..	Plymouth Institution and Devon and Cornwall Natural History.
PRESBURG ..	Association for Natural History.
QUEBEC ..	Literary and Historical Society.
ROME ..	Vatican Library.
	Regia Academia dei Lincei di Roma.
	Societa Italiana delle Scienze (detta dei XL.)
	Royal Geological Society of Italy.
ROUEN	Academy of Sciences.
SAN FRANCISCO	California State Geological Society.
ST. ANDREWS	University Library.
ST. LOUIS ..	Academy of Sciences.
ST. PETERSBURG	Imperial Academy.
	Central Physical Observatory of Russia.
	Imperial Russian Mineralogical Society.
STOCKHOLM ..	Royal Academy of Sciences, per Longman and Co., *Paternoster-row, London*; and Sampson and Wallis, *Stockholm*.
	Geological Survey of Sweden.
STRASBURG ..	Society of Natural Sciences.
STUTTGART ..	Association for Native Natural History.
TORONTO, C.W.	Canadian Institute, per Thomas Henning, Esq.
TOULOUSE ..	Academy of Sciences, Inscriptions, and Literature.
TRURO	Royal Institute of Cornwall.
TURIN	Royal Academy of Sciences.
UPSALA ..	Royal Society of Sciences.
VIENNA ..	Imperial Academy of Sciences.
	The Editor of the "Annual of the Imperial-Royal Geological Institute."
	Imperial-Royal Zoological and Botanical Society, per Braümuller and Co., *Vienna*.
WASHINGTON	Smithsonian Institution Library, per Mr. W. Wesley, 28, *Essex-street, Strand, London*.
WINDSOR ..	Royal Library.
ZURICH ..	Natural History Society.

ABSTRACT (1878).

The TREASURERS *in Account with* ROYAL GEOLOGICAL SOCIETY.

Dr. :—	£	s.	d.	Cr. :—	£	s.	d.
Balance (1st Jan., 1878),	35	14	0	Assistant Secretary, ...	15	0	0
Subscriptions, ...	44	17	6	Printing, ...	59	1	1
Dividends, ...	13	9	1	Sundries, ...	11	2	6
				Balance to Debit, ...	8	17	0
	£94	0	7		£94	0	7

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APPENDIX.

LIST OF FELLOWS, CORRECTED TO DECEMBER 31, 1880.

Fellows are requested to correct errors in this List, by Letter to the REV. DR. HAUGHTON, Treasurer, Trinity College, Dublin.

OFFICERS OF THE SOCIETY FOR THE YEAR 1881–82.

President.—Professor A. Leith Adams, F.R.S.

Vice-Presidents.—Earl of Enniskillen, F.R.S; Professor E. Hull, F.R.S.; Sir Robert Kane, F.R.S.; George H. Kinahan.

Treasurers.—Rev. Samuel Haughton, M. D.; Professor Samuel Downing, LL.D.

Secretaries.—Rev. Maxwell Close, F.G.S.; Valentine Ball, M.A., F.G.S.

Council.—W. Frazer, F.R.C.S.I.; J. Chetwode Crawley; Edward Hardman, F.C.S.; T. Maxwell Hutton; Hugh Leonard, F.G.S., M.R.I.A.; Professor A. Macalister, M.D.; Professor W. R. M'Nab, M.D.; Joseph O'Kelly; George Porte, M.R.I.A.; Robert S. Reeves; Professor J. Emerson Reynolds, M.D.; B. B. Stoney, C.E.; C. R. C. Tichborne, Ph.D., M.R.I.A.; Devonshire J. Rowan, M.D., M.R.I.A.

HONORARY FELLOWS.

Elected.

1844. 1. Boué, M. Ami, For. Mem. L.G.S., M.D., *Académie Imp. Sc., Vienna.*

1865. 2. Burton, Captain R. F., *Royal Geographical Society*, 1, *Savile Row, London.*

1861. 3. Daubrée, M., Membre de l'Institut, *Ecole Nationale des Mines*, 62, *Boulevart St. Michel, Paris.*

1861. 4. Delesse, M., Ingénieur des Mines, *Paris.*

1865. 5. Des Cloiseaux, M., Prof. of Mineralogy, *Jardin des Plantes, Paris.*

1861. 6. De Serres, M. Marcel, *Montpellier.*

1861. 7. Deville, M. H. Ste.-Claire, 8, *Rue des Vieux Colombières, Paris.*

1861. 8. De Koninck, M. L., For. Mem. L.G.S., *Liège.*

1861. 9. Geinitz, M. H. B., For. Mem. L.G.S., *Dresden.*

1863. 10. Hunt, Dr. T. Sterry, F. R. S., *Institute of Technology, Boston, U. S.*

1873. 11. Jones, Professor T. Rupert, F.R.S., *Powis Villa, Camberley, Farnborough Station.*

1861. 12. M'Clintock, Rear-Admiral Sir Leopold, R.N., C.B., F.R.S., 29, *Kensington Gate, London, S. W.*

HONORARY CORRESPONDING FELLOWS.

Elected.
1859. 1. Gordon, John, C. E., *India.*
1859. 2. Hargrave, Henry J. B., C. E., *India.*
1858. 3. Kingsmill, Thomas W., *Shanghai, China.*

FELLOWS WHO HAVE PAID LIFE COMPOSITION.

1853. 1. Allen, Richard Purdy, *Sycamore House, Brixton Hill, London, S. W.*
1857. 2. Carson, Rev. Joseph, D.D., S.F.T.C.D., *Trinity College.*
1857. 3. Dowse, Rt. Hon. Baron, 38, *Mountjoy-square, South.*
1872. 4. Durham, J. S. W., *Rosenthal, Torquay, Devon.*
1861. 5. Fottrell, Edward, *Drayton, Cambridge-road, Rathmines.*
1862. 6. Frazer, W., F.R.C.S.I., 20, *Harcourt-street.*
1857. 7. Greene, John Ball, 6, *Ely-place.*
1848. 8. Haughton, Rev. Professor, M. D., F.R.S., 40, *Trinity College*, or 31, *Upper Baggot-street.*
1862. 9. Henry, F. H., *Lodge Park, Straffan, county Kildare.*
1850. 10. Hone, Nathaniel, M.R.I.A., *St. Doulough's, county Dublin.*
1867. 11. Kane, Sir Robert, F.R.S., *Fortlands, Killiney, county Dublin.*
1866. 12. Lalor, J. J., 6, *Upper Fitzwilliam-street.*
1856. 13. Lentaigne, Sir John, M.D., 6, *Great Denmark-street.*
1851. 14. Malahide, Lord Talbot de, F.R.S., *Malahide Castle, Malahide.*
1876. 15. Mayne, Thomas, 5, *Williams' Park, Rathmines, Dublin.*
1846. 16. Murray, B. B., *County Survey Office, Downshire-road, Newry.*
1872. 17. O'Brien, William, *Ailesbury House, Merrion, county Dublin.*
1852. 18. O'Kelly, Joseph, 14, *Hume-street.*
1857. 19. Porter, William, C.E.
1864. 20. Symes, Richard Glascott, 14, *Hume-street.*
1851. 21. Whitty, Rev. John Irvine, LL.D, 94, *Lower Baggot-street.*

FELLOWS WHO HAVE PAID HALF LIFE COMPOSITION.*

1868. 1. Backhouse, Henry, 2, *Ontario-terrace.*
1879. 2. Barter, Rev. John Beaufort.
1875. 3. Boot, John Thomas, *Hucknall, Mansfield.*
1866. 4. Bradley, Samuel, *Little Castle, Castlecomer.*
1873. 5. Broughton, Frederick, LL.D., *Hamilton, Ontario.*
1862. 6. Carter, T. S., *Watlington Park, Watlington, Oxfordshire.*
1867. 7. Clark, George R., C.E., *Northern Bengal State Railway, Parbatipur, Dinagepore, Bengal.*
1854. 8. Clemes, John.

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* Extract from By-Laws.

"Any person not residing for more than sixty-three days in each year within twenty miles of Dublin shall be a Fellow for Life, or until he comes to reside within the above distance, on paying to the Treasurers the sum of £5 5*s*.

"Any non-resident Life Fellow who shall reside within twenty miles of Dublin for more than sixty-three days in any one year shall cease to be a Fellow, unless he shall either pay as additional composition of £5 5*s*., or shall pay a subscription of 10*s*. 6*d*. for each year in which he shall so reside for more than sixty-three days.

Elected.
1870. 9. Cooke, Samuel, C.E., *Civil Engineering College, Poona, Bombay.*
1873. 10. Cooper, J. A., M.D., *Civil Surgeon of Hissar Hissar, Bengal.*
1873. 11. Cox, Charles C., *Ashby House School, Walsall.*
1857. 12. Crawfurd, Robert, C.E.
1861. 13. Crosbie, William, *Ardfert Abbey, Ardfert, Tralee.*
1868. 14. Cruise, Richard J., *Geological Survey,* 14, *Hume-street, Dublin.*
1873. 15. Cunningham, Professor R. O., M.D. Edin., *Queen's College, Belfast.*
1874. 16. Devine, Thomas, *Deputy Surveyor-General for Ontario, Toronto, Canada.*
1873. 17. Dobbs, Josiah, *Coolbaun, Castlecomer, Kilkenny.*
1880. 18. Douglas, Lithgow, Robert A., *North Brink, Wisbech, Cambridgeshire.*
1880. 19. Dowdall, Rev. Launcelot Downing Dowdall, 9, *King's Parade, Clifton.*
1866. 20. Duffin, W. E. L'Estrange, *County Survey Office, Limerick.*
1861. 21. Dunally, Lord, *Kilboy, Nenagh.*
1876. 22. Dunscombe, Clement, M.A., C.E., *Public Offices, Derby.*
1866. 23. Ellis, R. H.
1871. 24. Emerson, Rev. J. M., 99, *Bushfield-avenue, Dublin.*
1869. 25. Enniskillen, Earl of, F.R.S., M.R.I.A., *Florence Court, Enniskillen.*
1872. 26. Gore, J. E., *care of C. S. Rundle, Esq., C.E., Umballa Post-office, Punjab, India.*
1871. 27. Hardman, E. T., 14, *Hume-street.*
1861. 28. Harte, W., C.E., *Donegal County Surveyor, Office, Londonderry.*
1856. 29. Haughton, Major John, R.A., *Bengal.*
1850. 30. Head, Henry, M.D., 7, *Fitzwilliam-square.*
1858. 31. Hill, J., C.E., *Ennis, county Clare.*
1862. 32. Hudson, R., F.R.S., F.L.S., *Clapham Common, London.*
1857. 33. Keane, Marcus, *Beech Park, Ennis, county Clare.*
1871. 34. Kelly, G. N. H., *Fair-street, Drogheda.*
1862. 35. Kinahan, G., J.P., *Roebuck Hill, Dundrum, county Dublin.*
1853. 36. Kinahan, George H., 14, *Hume-street.*
1862. 37. Kincaid, Joseph, Jun., C.E.
1874. 38. Laurence, Rev. Chas., *Lisreaghan, Laurencetown, county Galway.*
1858. 39. Leach, Lieut.-Colonel, R.E., 3, *St. James's-square, London, S.W.*
1868. 40. Leonard, Hugh, 14, *Hume-street.*
1875 41. Lilley, Rev. Charles, M.A., *Head Master of Ware Grammar School, Ware, Herts.*
1840. 42. Lindsay, Henry L., C.E., *Melbourne, care of J. Bower, Esq., C.E.,* 28, *South Frederick-street.*
1867. 43. Meadows, J. M'Carthy.
1874. 44. Meadows, Joseph, Jun., *Thornville, county Wexford.*
1840. 45. Montgomery, James E., M.R.I.A.
1856. 46. Moloney, C. P., *Capt. 25th Regiment, Madras N. I., per Messrs. Grindlay and Co.,* 3, *Cornhill, London.*
1856. 47. Medlicott, Henry B., F.G.S., *Geological Survey of India, per Mr. H. S. King, Cornhill, London, E.C.*
1857. 48. M'Ivor, Rev. James, *Rectory, Moyle, Newtownstewart, county Tyrone.*
1865. 49. Morton, G. H., 122, *London-road, Liverpool.*
1845. 50. Neville, John, C.E., M.R.I.A., *Dundalk.*
1870. 51. Nicolls, Thomas J. Inst. C.E., 3, *Maxwell Terrace, Pollokshields, Glasgow.*
1868. 52. Nolan, Joseph, 14, *Hume-street.*
1832. 53. Renny, Henry L., R.E., *Canada.*
1870. 54. Rigby, Jason, C.E., 49, *Park-avenue, Sandymount.*
1873. 55. Rowney, Professor T., Ph.D., *Queen's College, Galway.*
1875. 56. Scholfield, Amos, M.A., LL.D., *Cardiff, S.W.*
1854. 57. Scott, R. H., M.A., F.R.S., *Meteorological Office,* 116, *Victoria-street, London.*

Elected.
1872. 58. Sharpe, R. W.
1868. 59. Siree, P. H., C.E.
1854. 60. Smyth, W. W., F.R.S., *Jermyn-street, London.*
1865. 61. Steele, Rev. W., *Portora Royal School, Enniskillen.*
1871. 62. Sturman, Dr. E. A., 42 *and* 44 *Ennis-road, Strand Green-road, Finsbury-park Station, London, W.*
1857. 63. Tate, Alexander, C.E., *Queen's Elms, Belfast.*
1870. 64. Taylor, J. E., F.G.S., *Bracondale, Norwich.*
1866. 65. Townsend, H. W., *Clonakilty.*
1871. 66. Traill, William A., *Geol. Survey, Ballymena, Co. Antrim.*
1873. 67. Trench, J. Townsend, *Kenmare.*
1866. 68. Wall, H. P., *Portarlington.*
1864. 69. Waller, G. A., 2, *Longford-terrace, Monkstown, county Dublin.*
1880. 70. Watts, Robert George, M.D., 5, *Bulstrode-street, Cavendish-square, London.*
1853. 71. Webster, William B.
1871. 72. Weldon, Major Frank, per Messrs. Grindlay & Co., 3, *Cornhill, London.*
1872. 73. White, H. V., C.E., *County Surveyor, Longford.*
1872. 74. White, John N., *Waterford.*
1876. 75. Whiston, William, M.A., *Collegiate Academy, Chapel-Chorlton, near Newcastle, Staffordshire.*
1861. 76. Whitley, C. J., *Brisbane, Queensland.*
1846. 77. Wilson, Walter.
1864. 78. Wright, Joseph, *Cliftonville, Antrim-road, Belfast.*
1854. 79. Wyley, Andrew.
1857. 80. Wynne, Arthur B., F.G.S., *Geological Survey of India, Calcutta.*

ANNUAL FELLOWS.

1875. 1. Adams, Professor A. Leith, M.B., F.R.S., *Queen's College, Cork.*
1878. 2. Ball, Valentine, M.A., *Calcutta.*
1861. 3. Barrington, E. E., M.B., *Enniskerry.*
1862. 4. Barton, Henry M., 4, *Foster-place.*
1879. 5. Bowker, James, 9, *Royal Terrace W., Kingstown.*
1857. 6. Carte, Alexander, M.D., F.L.S., *Royal Dublin Society.*
1862. 7. Close, Rev. Maxwell, 40, *Lower Baggot-street, Dublin.*
1874. 8. Crawley, J. Chetwode, B.A., 3, *Ely-place, and* 66, *Mountjoy-square, W.*
1849. 9. Downing, Samuel, LL.D., C.E., *Trinity College*, or 4, *The Hill, Monkstown.*
1872. 10. Egan, F. W., *Geological Survey, Coleraine.*
1876. 11. Fitt, Decimus, C.E., *care of Messrs. Courtney & Stephens*, 2, *Blackhall-place.*
1865. 12. Fleming, John M., C.E., Surveyor, War Department, *Hong Kong.*
1866. 13. Foot, A. W., M.D., 49, *Lower Leeson-street.*
1858. 14. Gages, Alphonse, M.R.I.A, 51, *Stephen's-green.*
1857. 15. Hampton, Thomas, C.E., 6, *Ely-place.*
1870. 16. Hull, Edward, M.A., F.R.S., 14, *Hume-street.*
1865. 17. Hutton, T. M., 118, *Summer-hill.*
1866. 18. Knapp, W. H., C.E., *Wellington Lodge, Kingstown.*
1863. 19. Macalister, A., M.D., *Anatomical Museum, Trinity College.*
1878. 20. M'Henry, Alexander, *Geological Survey Office*, 14, *Hume-street, Dublin.*
1863. 21. M'Donnell, Alexander, C.E., *St. John's, Inchicore.*
1851. 22. M'Donnell, John, M.D., 32, *Upper Fitzwilliam-street.*
1876. 23. M'Nab, Professor W. R., M.D., *Royal College of Science.*

Elected.
1874. 24. Porte, George, 43, *Great Brunswick-street.*
1864. 25. Reynolds, J. Emerson, M.D., 62, *Morehampton-road.*
1857. 26. Reeves, Robert S., 5, *Fitzwilliam-place.*
1861. 27. Roberts, W. G., 7, *Cornwallis-terrace, Clifton, Bristol.*
1877. 28. Rochford, John, *Education Office, Marlborough-street, Dublin.*
1875. 29. Ross, George M., *Ballinagowan House, Rathmines.*
1862. 30. Rowan, D. J., C.E., 33, *North Frederick-street, Dublin.*
1861. 31. Stoney, Bindon, C.E., 42, *Wellington-road.*
1875. 32. Taylor, F. C., *Summerleaze Collegiate School, East Harptree, near Bristol.*
1880. 33. Taylor, John F., 3, *Ely-place, Dublin, and Middle Temple, London.*
1864. 34. Tichborne, C. R. C., Ph.D., F.C.S., *Apothecaries' Hall, Mary-street,* or 23, *Middle Gardiner-street.*
1863. 35. Westropp, W. H. S., M.R.I.A., *Lisdoonvarna, county Clare.*
1877. 36. Young, Peter, *Education Office, Marlborough-street, Dublin.*

SUMMARY.

Honorary Fellows,	12
Corresponding Fellows,	3
Life Fellows,	21
Half Life Fellows,	80
Annual Fellows,	36
Total,	152

SOCIETIES AND INSTITUTIONS TO WHICH THE JOURNAL OF THE ROYAL GEOLOGICAL SOCIETY OF IRELAND IS SENT.

ABERDEEN ..	University Library.
ALBANY ..	State Library, New York.
AMSTERDAM ..	Royal Academy of Sciences.
ANTWERP ..	Palæontological Society of Belgium.
BELFAST ..	Queen's College Library.
	Naturalists' Field Club.
BERLIN ..	Royal Prussian Academy of Sciences.
	German Geographical Society.
	German Geological Society, per Bessersche Buchhandlung, *Behrenstrasse*, 7, *Berlin*.
BOLOGNA ..	Academy of Sciences of the Institute.
BORDEAUX ..	Society of Physical and Natural Sciences.
BOSTON ..	American Academy of Arts and Sciences.
	Natural History Society.
BRISTOL ..	Institution for the Advancement of Science, Literature, and the Arts.
BRÜNN ..	Natural History Association.
BRUSSELS ..	Royal Academy of Sciences, Letters, and Fine Arts of Belgium.
CAEN	Linnæan Society of Normandy.
CALCUTTA ..	Asiatic Society.
	Public Library.
	Geological Survey of India.
CAMBRIDGE ..	Philosophical Society.
	Trinity College Library.
CANTERBURY, NEW ZEALAND ..	Geological Survey.
COPENHAGEN	Royal Danish Academy of Science and Letters.
CORK	Queen's College Library.
	Royal Institution.
DIJON	Academy of Sciences, Arts, and Literature.
DRESDEN ..	"Isis" Natural History Society.
DUBLIN ..	Royal College of Surgeons Library.
	Royal Irish Academy.
	University Library.
	Royal Dublin Society.
	Ordnance Survey Library.
	Geological Survey of Ireland.
	Institution of Civil Engineers.
EDINBURGH ..	Royal Society of Edinburgh.
	Edinburgh Geological Society.
	Royal Scottish Society of Arts.
	University Library.
	Society of Antiquaries.
	Advocates Library.
FALMOUTH ..	Royal Cornwall Polytechnic Society.
FLORENCE ..	Italian Society of Sciences.
GALWAY ..	Queen's College Library.
GENEVA ..	Society of Physics and Natural History.
GLASGOW ..	University.
	Glasgow Geological Society.
GÖTTINGEN ..	University.
HALLE ..	Natural History Association for Saxony and Thüringia, per Antons Buchhandlung, *Halle*.

HANAU ..	Upper-Hessian Society of Natural and Medical Science.
HANOVER ..	Royal Library.
HARLEM ..	Dutch Society of Exact and Natural Sciences.
	Teyler Institution.
KILKENNY ..	Archæological Association of Ireland.
KÖNIGSBERG	Royal Physical and Economical Society.
LAUSANNE ..	Vaudian Society of Natural Sciences.
LEEDS ..	Geological and Polytechnic Society of the West Riding of Yorkshire.
	Philosophical and Literary Society.
LEIPSIC ..	Royal Saxon Society of Sciences.
	University.
LIVERPOOL ..	Literary and Philosophical Society.
	Historic Society of Lancashire and Cheshire.
	Liverpool Geological Society, The Royal Institution, *Colquitt-street.*
LONDON ..	Geological Survey, *Jermyn-street.*
	British Museum.
	Society of Arts, *John-street, Adelphi.*
	Royal Institution, *Albemarle-street.*
	Royal Society, *Burlington House.*
	Geological Society, *Burlington House.*
	Linnæan Society, *Burlington House.*
	Royal Geographical Society, 15, *Whitehall-place.*
	Civil Engineers, Institution of, 25, *Great George-street, Westminster.*
	Royal Asiatic Society, 22, *Albemarle-street.*
	Royal College of Surgeons, *Lincoln's Inn.*
	Zoological Society, 11, *Hanover-square.*
	Geological Magazine, Editor of.
	Athenæum, 14, *Wellington-street, Strand, London, W. C.*
	Anthropological Society, 4, *St. Martin's-place, London, W. C.*
LYONS	Society of Agriculture, Natural History, and Useful Arts.
	Linnæan Society.
	Academy of Sciences, Literature, and Arts, per Treuttel & Wurtz, 19, *Rue de Lille, Paris.*
MADRID ..	Royal Academy of Sciences.
	Geographical Society.
MANCHESTER	Literary and Philosophical Society of.
	Manchester Geological Society.
MELBOURNE	Philosophical Institute of Victoria.
	Public Library, per Bain and Co., 1, *Haymarket, London.*
	Royal Society of Victoria.
MILAN	Royal Lombard Institution of Sciences.
MISSOURI ..	State Survey and University, *Geological Rooms, Columbia, U. S. A.*
MONTREAL ..	Natural History Society.
MUNICH ..	Royal Bavarian Academy of Sciences.
NANCY ..	Society of Sciences.
NEUFCHATEL	Society of Natural Sciences.
NEW HAVEN, U. S. A. ..	Connecticut Academy of Arts and Sciences.
	Editors of Silliman's Journal of Science and Art.
NEW YORK ..	State Museum of Natural History.
OXFORD ..	Bodleian Library.
	Ashmolean Society.
PALERMO ..	Academy of Sciences and Letters.
PARIS	Polytechnic School.
	Geological Society.
	School of Mines.
	Institute of France.
	National Library.
	Jardin des Plantes, Library.

PHILADELPHIA	American Philosophical Society.
	Academy of Natural Sciences, per Trübner and Co.
PISA	Tuscan Society of Natural Sciences.
PLYMOUTH ..	Plymouth Institution and Devon and Cornwall Natural History.
PRESBURG ..	Association for Natural History.
QUEBEC ..	Literary and Historical Society.
ROME ..	Vatican Library.
	Regia Academia dei Lincei di Roma.
	Societa Italiana delle Scienze (detta dei XL.)
	Royal Geological Society of Italy.
ROUEN	Academy of Sciences.
SAN FRANCISCO	California State Geological Society.
ST. ANDREWS	University Library.
ST. LOUIS ..	Academy of Sciences.
ST. PETERSBURG	Imperial Academy.
	Central Physical Observatory of Russia.
	Imperial Russian Mineralogical Society.
STOCKHOLM ..	Royal Academy of Sciences, per Longman and Co., *Paternoster-row, London;* and Sampson and Wallis, *Stockholm.*
	Geological Survey of Sweden.
STRASBURG ..	Society of Natural Sciences.
STUTTGART ..	Association for Native Natural History.
TORONTO, C.W.	Canadian Institute, per Thomas Henning, Esq.
TOULOUSE ..	Academy of Sciences, Inscriptions, and Literature.
TRURO	Royal Institute of Cornwall.
TURIN	Royal Academy of Sciences.
UPSALA ..	Royal Society of Sciences.
VIENNA ..	Imperial Academy of Sciences.
	The Editor of the "Annual of the Imperial-Royal Geological Institute."
	Imperial-Royal Zoological and Botanical Society, per Braümuller & Co., *Vienna.*
WASHINGTON	Smithsonian Institution Library, per Mr. W. Wesley, 28, *Essex-street, Strand, London.*
WINDSOR ..	Royal Library.
ZURICH ..	Natural History Society.

ABSTRACT (1880).

The TREASURERS *in Account with* ROYAL GEOLOGICAL SOCIETY.

Dr. :—	£	s.	d.	Cr. :—	£	s.	d.
Balance 1st Jan., 1880, ...	22	18	10	Assistant Secretary, ...	10	0	0
Subscriptions, ...	49	12	0	Printing, ...	25	18	0
Dividends, ...	13	7	5	Lithographing, ...	25	15	0
				Wages, ...	13	15	0
				Balance to Debit, ...	10	10	3
	£85	18	3		£85	18	3

31st December, 1880.

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